

Refining Economic Phenotypes for Genetic Analyses

Bethesda, Maryland
September 10–11, 2007

WORKSHOP SUMMARY

National Institute on Aging
Behavioral and Social Research Program

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LIST OF ACRONYMS

5-HTT	serotonin transporter
ACE effects	additive gene variance (A), common environmental variance (C), and unique environmental variance (E)
ADHD	attention deficit hyperactivity disorder
BART	Balloon Analogy Risk Tasking
BSR	Behavioral and Social Research Program
CCT	Columbia Card Task
DLPFC	dorsolateral prefrontal cortex
DOSPERT	Domain-Specific Risk-Taking
DSM	Diagnostic and Statistical Manual of Mental Disorders
fMRI	functional magnetic resonance imaging
HRS	Health and Retirement Study
MIDUS	Midlife in the United States
mOFC	medial orbitofrontal cortex
NIA	National Institute on Aging
NIH	National Institutes of Health
PA	program announcement
PET	positron emission tomography
PFC	prefrontal cortex
RFA	request for applications
SAT	Scholastic Aptitude Test
VLPFC	ventrolateral prefrontal cortex
VMPPFC	ventromedial prefrontal cortex

TABLE OF CONTENTS

Executive Summary	1
Emerging Themes	2
Suggested Next Steps.....	2
Introduction.....	4
Overview.....	5
Economic Theory (Laibson)	5
Health and Retirement Study (Weir)	8
Commentary:	
Genetically Informed Psychological Research on Income: Some Examples From the MIDUS Twin Study (Krueger).....	10
Integrating Genetic and Neural Mechanisms (Canli)	12
Challenges in the Search for Economic Phenotypes (Singer)	14
Discussion.....	15
Current State Of Individual Differences Research: Intertemporal Choice	17
Delay of Gratification (Mischel).....	17
Economic Models (Laibson; Benjamin)	20
Neuroeconomics of Aging (Hedden)	22
Commentary:	
What Is Self-Control and How Do We Measure It? (Duckworth)	24
Genetic Methods and Strategies (Krueger).....	25
Proposed Strategies From a Neuroscience Perspective (Canli).....	26
Discussion.....	27
Current State Of Individual Differences Research: Risk And Loss Aversion.....	28
Risk Taking and Loss Aversion (Weber).....	28
Biological Approaches to Risk Taking and Impulsivity (Blair)	32
Commentary:	
Synthesizing Approaches From Economics, Psychology, and Neuroscience (Krueger; Canli)	36
Discussion.....	37
General Discussion	39
Suggested Next Steps.....	41
Appendix 1: Participant Roster.....	44
Appendix 2: Workshop Agenda.....	47

EXECUTIVE SUMMARY

Many economic theories rely on the assumption of rational decisionmakers. However, these models often do not fit empirical data because they do not account for individual differences in cognitive, emotional, and social processes, many of which can be nonrational. Some of these individual differences might be apparent during childhood and represent stable traits or dispositions. Thus, economic theories might benefit from integration with disciplines focused on individual differences such as psychology, neurobiology, and molecular and quantitative genetics. To explore further next steps in research to more fully achieve this integration, on September 10–11, 2007, the National Institute on Aging (NIA) Behavioral and Social Research Program (BSR) convened a workshop, “Refining Economic Phenotypes for Genetic Analyses,” in Bethesda, Maryland. Drs. David Reiss and Erica Spotts on behalf of BSR and Dr. David Laibson of Harvard University organized and chaired the workshop. Each invited participant was asked to prepare a brief statement outlining his or her view on how research integrating genetics, psychology, and economics might best be advanced, with consideration given to the following questions:

1. What do you perceive to be the one or two pivotal findings from your own work in your field that have advanced or have the potential to advance our understanding of economic behavior or the genetics of economic behavior? Where do you see this line of research developing from here? How can it shed light on lifespan developmental issues or issues specific to aging?
2. How can we better specify the neurobiological and genetic mechanisms and pathways involved in economic behaviors? What are the conceptual and methodological advances required? What would help improve measurement of economic behaviors of interest?
3. What are the current pitfalls and obstacles to progress? Where are there gaps in our current knowledge that would be logical next steps for research?
4. From your perspective, how can [study of] individual differences help our understanding of economic behaviors of relevance to aging?

Following an overview of economic theory, research strategies and methods, and large-scale studies that could be used as a resource, workshop participants heard presentations and commentary focused on two behavioral domains—intertemporal choice and risk and loss aversion—and discussed ways to integrate neurobiology, economics, and molecular and quantitative genetics. Psychologists noted the importance of using economic measurements in their own work to explain behavioral or psychosocial outcomes, such as day-to-day decisionmaking and adherence to prescriptions. Likewise, economists acknowledged that psychological, neurobiological, and behavioral measurements could assist in explaining individual variations in economic behavior, identifying intermediate traits or pathways involved in economic behaviors, and understanding genetic influences on economic behavior. Thus, these measurements could ultimately aid in the refinement of existing economic models and the development of new ones.

Workshop participants expressed enthusiasm for an emerging interdisciplinary field focused on defining or refining economic phenotypes and genetic analysis. They were excited about learning from other disciplines and incorporating tools used by those disciplines into their own work. They made several suggestions for next steps (see below) but were especially enthusiastic about a collaborative project resulting in a framework that incorporates individual differences in behavior with economic phenotypes of interest.

Emerging Themes

- The complexity of economic phenotypes, including macrolevel, endolevel, and microlevel behaviors; the need to aggregate measures to downplay noise from individual experiments; and the need for agreement on the best variables to use.
- The complexity of psychological conditions and the need for a reductionist approach to identify areas of individual variation and determine which area will be of most interest to economists.
- The need for more study into the effects of aging, both in healthy adults and those with age-related diseases, on various aspects of economic behavior.
- The need for integration of economic, psychological, neurobiological, and genetic methods to further understand economic phenotypes and the need to learn from each discipline.
- Collaboration on developing causal models, distinguishing correlations from genuinely causal phenotypes, and using the best technology available.
- Engaging the wider community of scholars, including economists, as this field develops.
- Development of specific measures.
- Access to existing study samples and development of new ones.

Suggested Next Steps

- A collaborative and empirical project building on diverse economic phenotypes to create a highly ordered structure explaining individual differences. Such a project would use a large-scale study or take advantage of existing longitudinal studies to combine personality variables with economic phenotypes of interest. The NIA can support such a project through a request for application (RFA) or program announcement (PA), and it can assist in the selection of economic phenotypes on which to focus.
- Development of better measures, models, and standard language. New measures that respect domain and context specificity, portfolios listing measures that assess particular characteristics, and standardization of terminology are needed. The NIA can assist by identifying grant mechanisms for measures development and by working with professional societies to support initiatives.

- Workshops to cross-train economists, neuroscientists, and psychologists. Economists can learn more about the statistical tools psychologists use, psychologists can learn more about economics tools for managing and interpreting real-world data, and neuroscientists can determine how to map their approaches onto existing models. The NIA can support this effort by sponsoring workshops or by taking advantage of existing workshops such as those held by the Society for Neuroeconomics.
- Incorporation of cognitive psychology in future studies. The exploration of individual differences should account for mental representation, how knowledge is structured, and how behaviors adapt to and change environment.
- Studies of the effects of aging on economic phenotypes. Personality factors, age-related diseases, caregiver issues, and neuronal systems should be explored in the context of economic decisionmaking.
- A journal article to discuss issues in the field of economic phenotypes and genetics and to signal the NIA's interest in them. Such a publication could help workshop participants organize their thoughts and elicit responses from others in their fields.

**Behavioral and Social Research Program
National Institute on Aging**

**Workshop on Refining Economic Phenotypes
for Genetic Analyses
September 10–11, 2007**

INTRODUCTION

On September 10–11, 2007, the Behavioral and Social Research Program (BSR) of the National Institute on Aging (NIA) held an exploratory workshop to consider what could be gained by adding genetic analyses to attempts to understand economic behavior. Economists, psychologists, and neuroscientists discussed economic phenotypes, how these phenotypes could be measured, the level of analysis needed to assess individual differences within them, and how phenotypes might be influenced by aging. The workshop fostered the exchange of ideas and potential collaborations through formal presentations, invited commentary, and general discussion.

BSR has become a highly interdisciplinary program with a reputation for supporting large-scale research. It has incorporated behavioral genetics as a critical and central component of its portfolio, focusing in particular on social behaviors that are complex and have been difficult to address. BSR is one of the largest sponsors of economic research in the country, but it is by no means wedded to the assumption of rational actors long held in the field of economics. Indeed, some of the work supported by the NIA contradicts traditional economic paradigms.

Workshop participants were asked to consider the level of granularity needed to define and measure economic phenotypes and their components and which phenotypes to address first as well the types of activities BSR should support in personality research and why. The workshop agenda focused on two broad domains that appeared to be of most interest among investigators—exploring individual differences and economic behavior—but workshop participants considered how to divide these domains into manageable components and pointed out other economic domains worth pursuing. Organizers identified the rapidly developing fields of molecular and behavioral genetics and their potential value in contributing to our understanding of individual differences, and they expressed the hope that the use of genetics and associated neurobiology could provide more leverage within the economic sphere to more precisely tailor policies and interventions.

Throughout the workshop, both economists and psychologists discussed the limitations of their fields. Economists pointed out that categories of individual differences have been developed with little work to validate them and that the field now needs other disciplines to assist in determining what categories are most important. Psychologists, particularly personality psychologists, expressed similar concerns about how phenotypes have been defined. They agreed that future definitions should move beyond broad descriptions to incorporate variations both across and within individuals.

OVERVIEW

Economic Theory

David Laibson, Ph.D., Harvard University

Neuroeconomics is the study of the biological microfoundations of economic cognition. Biological microfoundations include neurochemical mechanisms and pathways (e.g., brain systems, neurons, genes, and neurotransmitters), whereas economic cognition involves mental representations, emotions, expectations, learning, memory, preferences, decisionmaking, and behavior. Laibson presented two case studies as examples, identified challenges, and discussed research frontiers.

In one study examining neuroimaging evidence on impulsivity, McClure et al. (*Science* 2004) used biological data to inform their economic analysis. They asked whether agents think differently about immediate versus delayed rewards and whether immediacy has an emotional drive/reward component. The investigators hypothesized that the limbic or dopaminergic reward system would show a disproportionate response to immediate rewards, whereas the analytic cortical systems would show similar levels of activation to both immediate and delayed rewards. Activation was observed in the mesolimbic dopamine reward system when study participants were given a choice between an immediate reward and a delayed one but activation in this region sharply fell when participants chose between two delayed rewards. Activation in the prefrontal cortex (PFC), however, showed no differences between choices that had an immediate reward in the choice set and choices that involved only delayed rewards in the choice set. Moreover, the activation of analytic regions corresponded to the ease or difficulty of a choice. Thus, the analytic system is sensitive to difficulty and makes little distinction between early and late, whereas the emotional or dopaminergic system disproportionately responds to decisions that have (potentially) immediate consequences.

In another study by de Quervain et al. (*Science* 2004), participants were asked to make a social exchange. Participant A made a decision to trust Participant B, Participant B chose whether to return the trust or to cheat, and Participant A's response to being cheated was measured. In one condition, A knew of B's intent to cheat and could punish B, but punishment was costly for both A and B. In a second condition, A knew of B's intent to cheat, and punishment was costly for B but free for A. In a third condition, A knew of B's intent to cheat but could only punish B symbolically, at no cost to A or B. In the fourth condition, B did not intend to cheat, but that intent was overridden by the computer; A could punish B, but punishment was costly for both A and B. The desire to punish depended on perceived unfairness and intentionality; A wanted to punish B only in cases where cheating had been intentional. Punishment also depended on the cost of that punishment; A punished the most when punishment was free and modestly when punishment was costly.

Neuroimaging results were consistent with these observations. Activation appeared in the nucleus caudate when Participant A perceived intentional unfairness and could punish Participant B for it. In conditions where punishment was symbolic or cheating was unintentional, however, activation of this region was at baseline. de Quervain et al. further explored possible correlations between nucleus caudate activation and the amount of punishment. Participants who punished for free and at the maximum rate showed varying levels of nucleus caudate activation,

and that response correlated with the amount of punishment implemented when it was costly. In other words, the level of satisfaction participants derived from free punishment predicted the amount of punishment they chose when it was costly. Thus, neurobiology can be used to understand and measure the degree to which individuals would punish others.

Economists tend to examine individual differences in factors such as time preferences; for example, by asking participants whether they would like \$10 now or \$20 in 30 days. Traditional measures also include other measures of preferential factors, such as risk aversion, loss aversion, and social preferences, along with measures of cognitive factors, such as analytic ability, social capital, or self-knowledge. Yet economists simply assume these areas to be important with little evidence to show that they are. These preference measures often do not predict behavioral variation, and in many cases, economists use competing paradigms for measurement. Differences in personality of conscientiousness, greed, ambition, need for achievement, and fear of failure have been ignored. How to measure these differences is not clear. Laboratory experiments, field data, incentive-compatible laboratory mechanisms (for example, Becker, DeGroot, Marschak), and questions about how one thinks others behave (Glaeser et al. 2001) are all possible methods. In addition, economists have historically asked abstract questions, eliminating the details of normal life. Yet people often use cues to answer questions, and richer questions might be needed. In addition, economists have focused on broader phenomena, such as discount or savings rates, but narrow behavioral domains (e.g. how aversive is waiting in line) might have more predictive power.

With respect to genetics, economists would like to identify sources of behavioral variation that arise from psychological/neural channels not previously identified. Molecular genetics is potentially promising. Whole-genome analyses have proven successful in identifying gene-environment interactions with respect to maltreatment in childhood (Caspi et al. *Science* 2003; Kim-Cohen et al. *Mol Psychiatry* 2006), episodic memory (Papassotiropoulos et al. *Science* 2006; Schaper et al. *Neurobiol Aging* 2007), coronary heart disease (McPherson et al. *Science* 2007; Helgadottir et al. *Science* 2007), diabetes (Sladek et al. *Nature* 2007; Saxena et al. *Science* 2007), and “seven common diseases” (Wellcome Trust Case Control Consortium *Nature* 2007). Molecular genetics can help economists to

- Explain variation by assessing direct gene effects and gene-environment interactions, identifying mechanisms, identifying causality, and using genes as control variables to improve inferences.
- Study behavioral responses to the environment. Economists study environmental variations that influence behavior, and gene-environment interactions can help them identify environmental variation with different effects across individuals.
- Provide individuals with information to help them make better decisions. This is a long-term goal.

As economists consider the use of genetics to study individual differences, they face several methodological hurdles. What the key phenotypes and interactions are and how to measure them are not clear. Likewise, how to find environmental interactions and avoid false positives, and whether efforts should be expended attempting to measure effects that might be too small to

detect in large populations, are not clear. Moreover, issues such as polygeny, epigenetic mechanisms, and copy-number variants also must be considered.

Laibson listed solutions that he acknowledged to be imperfect:

- Keep an open mind about the right phenotype.
- Follow people through the entire life course and provide rich measurements of environmental factors.
- Use large samples and replicate findings.
- Use priors to test functional pathways.

The use of genetics to inform economic study must also account for ethical issues. For example, most people do not understand what it means to consent to a genetic study and what the risks are. In addition, the meaning of genetic information obtained from a study is often not clear. Potential harm to a participant's relatives and to broader social groups to which the participant belongs must be considered, particularly in light of possible misinterpretation by the media. The NIA, and more broadly the National Institutes of Health (NIH), can play a role in addressing these issues by creating benchmarks and guidelines outlining the researcher's obligation to study participants and their relatives. These guidelines should address standards of clinical diagnosis, participants' right to know, how to interact with participants who do not want to know about their genetic status, and what to do about information that is not actionable.

Costs and benefits must also be weighed. Genetic analyses are still expensive, and their applications to the social sciences are highly speculative. Yet costs are falling rapidly, by a factor of 100 every 10 years, and methodology is constantly changing. Laibson suggested a short-run strategy of collecting and storing DNA samples from participants in important surveys, then pursuing research programs with high option values. Such a strategy would involve a modest initial investment, followed by more resources if the research is successful.

Discussion and Comment

Economists can look to health instruments to assess effects of health issues on economic outcomes. Smoking was discussed as an example. A dataset collected in the late 1990s by a group at the University of Pennsylvania's Transdisciplinary Tobacco Use Research Center was used to examine the effects of health states such as obesity and depression and health behaviors such as smoking on academic outcomes. Gender differences as well as omitted variable bias when excluding comorbid health conditions were observed. This represented a first step toward defining smoking as an economic phenotype. Workshop participants noted that many of these types of studies examine the genotype for the body itself but not for the central nervous system. Yet these studies open the way for interesting areas of economic variation. Obesity was cited as another example.

Motivation was suggested as another area in which to explore individual differences. For example, the same motive can be expressed in different ways depending on environment.

When assessing genetic variation, it should be noted that much of the literature describing genetic markers of predisposition does not discuss the individuals who have those markers but do not develop the health outcome. Risk involves a large environmental component, but this component is often ignored. Workshop participants emphasized that “the gene for X” is an incorrect expression because other genes and environmental factors might protect from or exacerbate risk. Again, participants noted the problem of communicating with the general public.

Health and Retirement Study

David Weir, Ph.D., University of Michigan

The Health and Retirement Study (HRS) is a cooperative agreement between the NIA and the Survey Research Center of the Institute for Social Research, University of Michigan. The HRS serves the needs of behavioral and social research on aging. It is open source with input into the design and ongoing innovation of the study by investigators, staff, and advisors. The study also offers rapid public release of its data for widespread use, and it already has been used in papers by approximately 1,000 authors. The HRS is now well positioned to support research into the genetics of behavior.

The HRS began in 1992 with a cohort of participants aged 51 to 61 years who were followed every 2 years. Refreshment cohorts were added every 6 years to enable the study to continue indefinitely. Core areas of interest include

- **Basic health**, including self-reported conditions and behaviors and cognitive testing.
- **Health services**, including use, expenses, and out-of-pocket spending.
- **Labor force**, including employment status and history, earnings, disability, retirement, and type of work.
- **Economic status**, including income by source, wealth by asset type, capital gains/debt, and consumption with linkage to pensions and Social Security earnings benefit histories.
- **Family structure**, including extended family, proximity, money transfers, time, and housing.

Biological measures including blood spots, DNA, physical performance measures, anthropometry, blood pressure, and psychosocial questionnaires were added in 2006. Completion rates for these measures are fairly high, and the informed consent for these samples is general and allows for a wide range of research. A DNA repository has been established with about 6,800 samples from the 2006 wave. A similar number of samples is expected for the 2008 wave. Difficult decisions lie ahead in terms of how and when to use this repository, however. An ideal solution would involve complete sequencing of all samples with computerized data available to qualified researchers under secure conditions. Yet sequencing is still an expensive endeavor.

The HRS contains economic measures designed to support traditional research and to monitor the economic status of the elderly. These measures reflect a lifetime of behavioral and external factors. The HRS is innovative in that it includes measures of behavioral economics, or preferences. These factors include risk tolerance, patience, trust, and “planfulness” and are likely

to be more phenotypic than traditional economic outcome variables, although not all economists consider them to be domains of economic science.

Those involved in the HRS design and innovation have considered several approaches to measurement, including experimental manipulation, hypothetical scenarios, psychological assessment, and recall behavior. However, the best form of measurement and which concepts are most important are still under deliberation. With regard to risk, economists assert that there exists an optimal tradeoff between the amount of risk and the amount of reward, familiarly known as “greater risk, greater reward.” However, in some cases, more is not always better. The HRS has used a hypothetical scenario to assess risk tolerance, but because it is lengthy and out of the realm of experience for many people, this measure has limited predictive power. Hypothetical scenarios are used to assess patience, but again, the scenario is often difficult and out of the realm of real-life choices, and it is difficult to present visually. “Planfulness” is assessed by a question about what participants think is most important in terms of planning horizons. The HRS uses an Internet survey to overcome some of these challenges. For example, participants can click on a column showing their current consumption, and they can see the effects of immediate consumption on future consumption.

Genetic analysis also is expected to provide more focus. Traits with demonstrated genetic links will receive more attention, and measurements that sharpen those links will receive more use. If genes do in fact influence behavior, they will do so through biological pathways. Identifying the biological origins of behavior will provide a middle ground between the raw correlation of genes and behavioral traits, and it will suggest biological approaches to measurement. This will be especially true in studies of the elderly, which must account for how behavior is shaped by many years of environmental exposure.

Discussion and Comment

The economic components of the HRS include some measures of numeracy. Although these measures are not rich, they have revealed low numeracy among many respondents. Thus, hypothetical scenarios might have some value, but other measures will be needed. Workshop participants discussed studies by Carstensen et al. suggesting that people become more patient when time horizons are shorter. Another study that has measured discount rates also shows that participants become more patient as they get older, although the level of patience decreases if time horizons are extended.

The HRS is a rich resource for exploring individual differences among economic phenotypes. Workshop participants suggested combining this dataset with those from other, possibly complementary longitudinal studies to generate information that is even more comprehensive. Dr. David Weir stated that the HRS is willing to work with other groups with potentially interesting economic phenotypes and to share its phenotypes with others.

Some participants expressed concern about Weir’s prediction that genetic effects that show a correlation with currently-measured economic phenotypes will receive the greatest attention by researchers. These participants noted the possibility that more longitudinal or intergenerational correlations might be missed. Weir clarified that although genetic effects showing more immediate correlations most likely will receive priority because of such pressures as the need to

publish findings, longer term correlations will still be of interest and are addressable using HRS. Other participants asked whether data were collected on accumulated life stress and whether one could access that data and look at DNA samples to assess possible interactions. Weir reminded workshop participants that this facet of the HRS is still fairly new. The psychosocial questionnaire includes major life events and links between socioeconomic status and health, for example, but improvements will be needed.

Commentary

Genetically Informed Psychological Research on Income: Some Examples From the MIDUS Twin Study

Robert Krueger, Ph.D., University of Minnesota

Two lines of research can be relevant to the refinement of economic phenotypes. One involves measurement and conceptualization of externalizing phenomena on psychological construct; for example, impulsivity (Krueger et al. *J Abnormal Psychol* in press). Dr. Robert Krueger focused his comments on a line of research represented by the Midlife in the United States (MIDUS) study, a large-scale twin study housed at the University of Wisconsin. Unlike other twin study samples, which rely on birth registries, the MIDUS sample was constructed through random-digit dialing, and thus, the MIDUS sample is distributed throughout the continental United States.

Data showing that personality is heritable have had an enormous impact on psychological research. However, the field of personality psychology has long been a contentious one, as most of the work has focused on what personality is, how to conceptualize and measure it, and how it relates to behavior. There does appear to be a genetic basis for personality, suggesting that personality is an important psychological construct. Yet heritability studies have often presented personality as static, regardless of individual or circumstances. Krueger argued that overall heritability in a population does not preclude the dynamic aspects of personality, and he discussed subpopulation heterogeneity in genetic and environmental effects, more familiarly classified as gene-environment interactions. Work by Krueger and his colleagues attempts to tie together two historically separate lines of research: Personality and the relationship between health and income.

Twin studies typically decompose phenotypic variation into three sources. The first comprises additive genetic effects, usually designated “A.” Twin pairs differ in genetic resemblance. They are identical (monozygotic) or fraternal (dizygotic). If genetic variation could completely explain phenotype, then the monozygotic correlation would be 1.0 and the dizygotic correlation would be 0.5, and expectations could be adjusted for more complex genetic effects such as dominance or epistasis. The second source of variation is the common experience, designated “C.” Twins reared together share a common experience regardless of zygosity. If this experience could completely explain phenotype, then twins reared together would be expected to have the same phenotype. The third source is the unique environment, designated “E,” which assumes that people within a family differ for environmental reasons. Twins are not phenotypically identical. If unique environment completely explained phenotype, then no correlations should be seen between twins. Essentially, they appear as two random people.

Traditionally, twin research has been based on estimates of any one component to show genetic effects on phenotype. However, more sophisticated modeling and statistical techniques are now available to incorporate A, C, and E into gene-environment interactions. In addition, investigators can now look for hot spots to examine places where environmental variation is changing. Moreover, traditional estimations of ACE effects in the gene-environment interaction do not account for different architectures among subpopulations. Thus, not enough information is available to characterize situations. By directly modeling the raw data, investigators can now characterize continuous heterogeneity in ACE effects.

Several epidemiologic studies have linked lower income to disease incidence. This relationship transcends disease categories and is monotonic across the range of income. Krueger et al. also found that genetic contributions to health were enhanced at lower incomes. They further examined household income, number of chronic physical illnesses, current height and weight, and individuals' perceptions of control. In so doing, the investigators found that genetic contributions to health were enhanced not only by lower income, as demonstrated before, but also by lower sense of control. Thus, individual differences in a psychological variable were just as important in genetic effects as were putatively objective factors such as income. Similar results were observed for body mass index.

Previous research also has demonstrated a weak relationship between economic resources and life satisfaction in developed nations. Lykken proposed a genetic "set point," wherein genetic effects on happiness might override the effects of external circumstances. Krueger et al. hypothesized that although economic resources do not contribute directly to happiness, they may contribute to the clarity with which happiness is expressed. In other words, fewer economic resources provide circumstances for unwelcome shocks to life satisfaction, whereas more resources might buffer an individual. Krueger and his colleagues examined finances, a composite of income and assets, and life satisfaction, measured based on individuals' satisfaction with their life and themselves and their perception that they were living the best possible life. As expected, genetic variation and common environment were constant, but the E component, in this case random shock, affected the ability to express genetic variations in happiness, and random shock was enhanced at lower finance levels.

It is thus important to note that genetic effects are salient contributors to variation. Yet this is just a start. Personality can moderate outcomes, and putatively objective circumstances can modulate personality. The ability to identify dynamic aspects of personality requires genetically informative data and will depend on the ability to disambiguate genetic and environmental sources of variation.

Discussion and Comment

Workshop participants pointed out that for polygenic or complex traits, not controlling for factors such as race and ethnicity could be problematic. Income might interact with race/ethnicity, and more genetic mixing could occur at lower income levels. This interaction should be studied empirically, and several companies can assist in measuring and controlling for the degree of stratification. Others raised the question of causality. For example, people of low physical health might have a lower sense of control. Krueger clarified that with nonexperimental data, findings are further complicated because of dynamics over time.

The studies by Krueger et al. are good examples of how twin data can be used to understand mediating factors. They also demonstrate that work linking typologies to complex genetic interactions and complex behaviors can be done. How broad one's perception of control is—for example, how it is affected by family life, academic life, or economic life—can be tricky. Some of it can be studied empirically, but different pieces of personality psychology must be brought together to fully understand how to marry broader individual differences with how these differences are moderated.

It should be noted that not only can genetics inform economic analysis; economic perspectives, techniques, and accomplishments can inform genetic analyses as well.

Integrating Genetic and Neural Mechanisms

Turhan Canli, Ph.D., Stony Brook University

The use of imaging genetics to explore the complex trait of neuroticism began with a study by Lesch et al. (*Science* 1996), who found that differences in the degree of self-reported neuroticism correlated with variants of the serotonin (5-HTT) gene. Specifically, more neuroticism was reported by carriers of the short allele than by those homozygous for the long allele. Yet the literature following up this basic association has been inconclusive. Approximately 30 studies have been done to date, and only half of them have replicated the initial findings. Meta-analyses have suggested a small but significant association between the short allele and neuroticism, but the degree of that association depends on how the meta-analysis was done. Thus, attempts to replicate the Lesch findings have been complicated by the attempt to move from molecular differences to self-reported behavior.

The same can be said for impulsivity, which was defined by Dr. Turhan Canli as a predisposition to respond to events without regard to consequences. Many forms of psychopathology involve some element of impulsivity, and the trait itself has some heritability. Yet impulsivity is most likely a polygenic trait involving serotonergic and dopaminergic genes, and there are several ways to parse it.

Previous studies of impulsivity have been limited first by an overreliance on categories listed in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM). Many of these categories are not rooted in biology, and many include several elements. Previous studies also have been limited by an overreliance on self-report measures, which are vague, subjective, and superficial. Many of these studies have made inferences about impulsivity based on task performance but have used inappropriate tasks; for example, a task involving executive working memory. Thus, these studies have attempted to analyze phenotypes based on broad descriptions.

Canli suggested the use of endophenotypes as a solution in analyzing complex phenotypes. Personality can be deconstructed into vertical domains of psychological processes including affective experience, attention, perception, and memory. Deconstructing personality into these processes provides an experimentally rigorous way to assess individual differences and builds on the well-validated task paradigms of psychology and cognitive neuroscience. This approach also takes advantage of previously identified genetic networks underlying biological processes. In other words, diagnostic categories can be decomposed into trait dimensions, which can be decomposed further into behavioral dimensions, neurobiological systems, and genetic factors.

Brain activation is a critical intervening variable, and thus, a candidate endophenotype between genetic variation and self-reported behavior. This was demonstrated with respect to 5-HTT by Hariri et al. (2002), who compared brain activation during a face-matching task with that during a visual-spatial matching task. The investigators observed higher reactivity in the amygdala in response to the negative faces in carriers of the short allele. This result was replicated by Fumark et al. (2004), who used positron emission tomography (PET) to compare blood flow in social phobics in an anxiety-provoking condition versus that in a neutral one. The result was further replicated in studies by Heinz et al. (2005), who examined amygdala reactivity by genotype, and by Canli et al. (2005), who measured activation relative to a word recognition test. These studies used different tasks, and all had small sample sizes, but they showed the same result with regard to brain region activation. Thus, an imaging-based endophenotype provides greater sensitivity than self-report.

Although functional magnetic resonance imaging (fMRI) is a dynamic tool for assessing individual differences, it is somewhat problematic in terms of interpreting data. fMRI studies are constrained to comparing two conditions, and differences between these two conditions could be ambiguous. For example, one could say that more amygdala activation is seen in response to the negative condition, but one also could say that less activation occurs in the neutral condition. There is no way to dissociate one statement from another, and in many cases, the brain is assumed to be inert in the neutral condition. Another interpretation, although not intuitive, is that the brain shows a baseline elevation in amygdala activation that declines when a participant is placed in a neutral condition.

Canli et al. addressed this problem by introducing a second baseline: A fixation rest in which participants lie in a scanner and do nothing. They compared this baseline with the neutral condition and with the negative condition and found deactivation in the amygdala when participants were placed in the neutral condition. In contrast, no elevation in activation was observed in the negative condition compared with the fixation rest baseline. Thus, the observed differences in amygdala activation were driven primarily by deactivation in the neutral condition. These results, replicated by Heinz et al. (2007), suggest a tonic model in which individuals with the shorter 5-HTT allele exhibit an elevated level of amygdala activation that decreases under neutral conditions.

Even with a second baseline, however, studies based solely on fMRI will have some ambiguity because whatever is concluded for one condition could have an inverse interpretation in the other condition. This problem can be addressed by multimodal imaging; for example, by adding perfusion imaging. This modality measures absolute blood flow, eliminating the need to infer the meaning of differences in activation. Using this imaging modality, Canli et al. (*Proc Natl Acad Sci U S A* 2006) observed elevated blood flow in individuals with the short 5-HTT allele compared with individuals with the long allele, even when individuals were at rest. These observations were confirmed independently in a study by Rao et al. (*Biol Psychiatry* in press).

Environment also must be considered. As discussed by others at the workshop, Caspi et al. (2003) found that the effect of life stress on depression is moderated by the presence of the short 5-HTT allele. Canli et al. found a positive correlation between self-reported life stress and amygdala activation in carriers of the short allele, whereas the correlation was negative in participants who were homozygous for the long allele. Carriers of the short allele also appeared

to have less life stress than participants homozygous for the long allele, suggesting that individuals might regulate their response to the environment; for example, by removing factors that stress them.

These studies suggest a model of vulnerability versus resilience in which genetic susceptibility interacts with environment to render an individual vulnerable to psychopathology. However, the sample sizes were too small to determine how much each variable contributes to certain behaviors. Animal studies have focused on molecular mechanisms and the impact of life experience on epigenetics.

Canli cautioned that many studies focused on endophenotypes use small sample sizes. Thus, replication is critical. He also likened large-scale datasets to ocean liners, as they cannot be changed quickly in response to new discoveries or changing conditions. Investigators must therefore think more critically about setting initial conditions and incorporate flexibility in terms of post hoc genetic analyses and data sharing.

Lessons from the study of 5-HTT and neuroticism could be applied to impulsivity or other traits relevant to economic behavior. The term “economic behavior” is too vague and should be broken down into endophenotypes. It is possible that the neural and molecular phenotypes underlying gene-environment interactions could become a major focus in the genetic analyses of economic behavior, with environment representing life experience or other aging-related factors.

Challenges in the Search for Economic Phenotypes

Burton Singer, Ph.D., Princeton University

Genetic analysis of economic behavior is still awaiting a good, tightly constructed notion of phenotype in an economic context. Even in association studies linking behavior to genotype involves not a specific genotype but a combination of many.

Gene-environment interactions are especially important. As Krueger noted, outcome variance increases further down the socioeconomic hierarchy. As noted by a vast amount of literature, the further down someone is in social status, whether by education, income, or other factors, the worse off that person is on several outcome measures. However, that statement simply addresses the mean; it does not address the increasing variance that is observed at lower levels of the hierarchy, nor does it address the fact that a considerable number of people at the bottom do just as well in outcomes as those at the top. Assessing the environment will help in determining how those people do well, and that kind of knowledge can lead to studies about ways to prevent negative outcomes.

Yet that line of inquiry does not receive the attention it deserves. For example, the second of the Caspi studies associated the short 5-HTT allele with depression, but the authors did not point out that many individuals with this genotype do not suffer from depression. It is difficult to blame the media for the negative leaning of these studies as the media obtains its information primarily from the scientific literature. In addition, the literature is driven heavily by the biomedical and pharmacological communities that are more focused on disease and how to alleviate it and less on prevention. Thus, a focus on negative outcomes is natural. However, several questions regarding protective measures should be addressed.

Dr. Burton Singer and his colleagues are working to develop taxonomies of life histories through health outcomes. However, he pointed out that focusing on health outcomes is too distant. Studies should determine whether there are biomarkers that can predict health outcomes then determine what types of life histories lead to different combinations in the expression of those biomarkers. Singer pointed out that, in his experience, the problem has not been too few cases. The problem has been too much information; for example, thousands of variables over 40 to 50 years of life history. How to distill this information and whether the empirically based taxonomies of life histories that come out of such a process will be associated with end points are not clear. Singer pointed out that psychosocial profiles are not tuned to the biology, and many psychological measures were not developed with genetics in mind.

This is a limitation to focusing on surveys that might be data rich. Singer cited as an example one survey where whole groups were “off the chart” in terms of biomarkers predictive of cardiovascular disease. Singer et al. were able to conduct face-to-face interviews, and they asked participants to write about the worst and best experiences of their lives. In doing so, participants provided valuable qualitative information. Singer expressed a preference for the qualitative information derived from the writing test and interview to the information derived from genetics because of the primitive state of biomarkers at this point in time.

Discussion

Canli noted that effect sizes for genes associated with self-reported behavior were six to eight times smaller than those for genes associated with brain phenotypes. He also cautioned that a degree of publication bias exists. The first results that are published tend to have a larger effect size than any followup studies, and they may therefore overemphasize the degree to which a particular gene affects the substrate. Canli expressed concern that such a bias leads to negative results not being reported, yet these studies are just as important in understanding the relationships of genetics to phenotypes. Reiss added that most genetics imaging studies exclude participants with significant psychopathology. Similarly, studies focused on economic behavior will have to limit the economic range and other characteristics of the sample.

Differences in measurement error across various types of studies were cited as another caveat. fMRI studies tend to be based on hundreds of trials, whereas self-report studies are based on a few questions, and economic studies are based on even fewer questions. These differences in measurement error might not completely explain differences in effect sizes, but they should be considered in any comparison. The larger effect size for genetic correlations in fMRI versus behavioral studies could result from the reliability of the measure. Yet genetics imaging studies have not paid much attention to reliability, and the accumulation of behavioral literature has not yielded a behavioral phenotype that is highly powerful in identifying genetic effects. Dr. Joseph Callicott agreed that endophenotypes are much closer to the gene than a broadly described behavior, but he pointed out that constructing a neuroeconomic phenotype does not necessarily require a scanner. Investigators should consider their measurements, particularly how frequently they measure and how often they repeat it.

Krueger posed a hypothetical scenario in which a behavioral measure has 10 observations on a self-report scale, and he questioned how effect size would be influenced if only 10 observations from an imaging study were used. However, 10 items on a self-report scale are not the same as

10 imaging trials, partly because self-report questions are designed to remove situational variants. Krueger discussed psychometrics, which traditionally has not been considered by economists. Psychometrics do not focus on an overall reliability index. Rather, they focus on latent traits, and the level of reliability depends on the level of the trait. Genetic analyses of economic behavior will require formal measurements that account for psychometric developments, an understanding of the level at which a trait is assessed, and ultimately, the identification of appropriate items to test.

Workshop participants agreed on the need to collect as much data as possible using multiple approaches, each of which is an imperfect measurement of a central trait. fMRI studies are powerful and can overcome the problem of false positives, but they also can be expensive and time consuming. Yet imaging is not the only way to collect data on endophenotypes. Performance on a cognitive task might provide a more precise measure of some aspect of behavior than a response to a personality question, but it is possible that the selected endophenotype would not measure well in genetic analyses. Approaches such as electrophysiology and social survey could be more useful at a larger level. With a large amount of data from multiple approaches converging on a particular phenotype, investigators can feel more confident moving forward. Workshop participants also discussed the value of conducting human and animal studies in parallel, which will require several laboratories to work together in a coordinated fashion.

Discussion turned to economic phenotypes. Laibson mentioned a Swedish twin study showing a high rate of heritability in game outcomes, and he referred to the Danish twin study, cited during his presentation, where wealth was shown to be heritable and highly correlated with genetics. Wealth is a highly downstream variable resulting most likely from an accumulation of many decisions over the life course. A well-measured trait that reflects this accumulated decisionmaking could be a promising phenotype to explore in genetic analyses. However, any analysis must consider the possibility that many genes work at many levels to produce an effect.

Gene-environment interactions also must be considered. As discussed by Singer, not everyone with a genetic disposition toward an outcome experiences that outcome. For example, wealth was once seen as a purely environmental variable, exogenous to the biological system. Often, discussions of gene-environment interactions do not account for the influence of a person on his or her environment or long-term correlations between genetic effects and/or distal outcomes. Genetic analyses of behavior also do not account for developmental trajectories. In addition, although investigators may identify protective haplotypes or environmental factors, journal editors often ask them to remove this information from their papers to strengthen the genetic correlation with a phenotype or behavior. Workshop participants discussed the Caspi study correlating 5-HTT genotype with depression, which has not been reliably replicated. Some followup studies did not take environment or context into account, and other studies found that other variables such as age, sex, and social support modified genetic risk. Timing is another factor, as pointed out by Dr. Niels Rosenquist. Studies should assess not only what affects a particular phenotype, but when the effect occurs.

Genetic analyses also must account for the multiple effects of a particular gene. Not so long ago, associations were limited to one gene and one disease. Now it is necessary to consider that one gene could regulate several neuroregulatory systems and that the impact of that gene on behavior

is the product of multiple impacts or multiple genes. This will present an enormous challenge in correlating genes with phenotype and behavior. The categorical DSM approach is therefore not useful when assessing the functional consequences of genes. This approach often compares a cohort of patients with a particular disorder with a cohort of control patients, but it does not address the activity of a gene across DSM categories.

Workshop participants discussed what economists want to accomplish by incorporating psychological considerations in their research. Laibson suggested that economists would like new ways to explain individual variations that are complementary to what has already been done. They also want to understand the pitfalls that scientists from other disciplines have faced in their studies and the best practices for understanding connections between genetic pathways and behavior. Traditionally, economists have focused on outcomes such as the labor market; human, financial, and physical capital accumulation; family dynamics; reproduction and family formation; and social networks. Behavioral scientists might help identify intermediate traits or pathways that would play influential roles in the behaviors of interest to economists. Yet the wealth of possibilities presents a problem. Economists and behavioral scientists would have to determine which among the hundreds of possibilities would be the best to pursue.

Likewise, workshop participants were asked to consider what behavioral scientists might derive from the economic analysis of behavior. Results from economic measurements could be applied broadly to behavioral and psychosocial outcomes. What motivates day-to-day decisionmaking or what influences a decision to enroll in Medicare Part D, follow an exercise regimen, or adhere to prescriptions were listed as examples.

CURRENT STATE OF INDIVIDUAL DIFFERENCES RESEARCH: INTERTEMPORAL CHOICE

Delay of Gratification

Walter Mischel, Ph.D., Columbia University

Dr. Walter Mischel and his colleagues have studied choice behavior, particularly with respect to delay of gratification. Through several studies, they have found that delay behaviors, be they criminal behavior, long-term or short-term planning, need achievement, or social responsibility, depend on the type of temporal delay and the value of the reward. Yet they also depend on trust expectations, the mental representation of the object of desire, and developmental correlates such as age. Mischel found that while choices between smaller but sooner versus larger but later rewards were of interest as indicators of temporal discounting and had diverse, interesting correlates, at best they were only modestly linked to self-control behavior and the ability to persist for chosen delayed gratifications in the face of immediate temptations. Therefore, Mischel developed a new paradigm for delay of gratification by studying children at Stanford University from 1968 through 1974. Study participants are now about 45 years of age, and Mischel and his colleagues continue to study them and their children.

The prototypical delay-of-gratification experiment had a child waiting in the “hot condition,” where one Oreo cookie was on one side of the plate, two cookies were on the other side of the plate, and the experiment ended when the child rang a bell. The child understood the contingency; you can ring the bell and get the smaller reward or wait for the experimenter’s

return (20 minutes later) and get the larger reward. Trust expectations were controlled: The children knew they would get the object of desire because it was there for them to see. Mischel played video clips to illustrate the vast individual differences observed, but for the most part, children who were 5.5 to 6 years old were able to delay, using various mechanisms of willpower, whereas younger children were not. Mischel and colleagues initially hypothesized that delay would be easiest if rewards were visually available. However, this hypothesis was wrong; children were better able to wait when the cookies were placed under the plate. Anyone could wait when the reward was obscured.

To determine how representation influences delay behavior, Mischel et al. had children look at realistic, life-sized images of a desired object. When children were waiting for cookies and they saw an image of a cookie, they were better able to wait. Having a pictorial representation of the desired object made the decision to delay easier. How the object was primed was also a factor in the decision to delay. If children were told to make believe the reward was real, they were less likely to delay. If they were told to make believe the reward was a picture, however, they were better able to delay. For example, if a child looked at a marshmallow and pretended it was cotton or a puffy cloud, they could wait. Thus, placing an abstract object in “cool” terms enabled delay, whereas placing it in “hot” terms made it harder to wait. On the basis of these results, Metcalfe and Mischel (*Psychol Rev* 1999) proposed that two systems—a hot, “go,” motivational system and a cool, “know,” cognitive system—interact continuously and that both systems are activated under conditions where delay is easiest. Individuals retain motivation by “heating it up,” but they do not let the motivation become so arousing that they can no longer delay. When their studies began to follow eye movements or attention strategies, Mischel et al. found that delay was easier when the participant’s eyes moved back and forth from the object to distraction.

In predicting long-term correlations, however, one has to distinguish between the diagnostic (hot, reward-exposed) condition and the nondiagnostic (cool, reward-obscured) condition. Surprisingly, Mischel et al. found outcome correlations only for the diagnostic condition. In one small followup study with the Stanford study participants, delay time when those participants were children correlated with Scholastic Aptitude Test (SAT) scores obtained from the Educational Testing System. The basic longitudinal findings from the Stanford study were also replicated with demographically appropriate measures in a shorter term prospective study with middle school inner-city Bronx children. In another study, children aged 7 to 17 years who were at a camp for youth at risk for aggression or depression had to choose between a small amount of M&M candies now and a larger pile later. In this study, ability to delay gratification in the experimental conditions was correlated negatively with the amount of their verbal or physical aggression, as measured at the camp. Neither study relied on self-report. The Barnard Toddler Study examined attention strategies among 18-month-olds when they were separated from, then reunited with, their mothers. The distraction strategies they used at this age to facilitate their ability to delay were predictive of their delay time when they performed the delay task in preschool and in turn linked to their performance on go–no go tasks at age 18 years.

Followup studies of the Stanford and Bronx cohorts looked at the combination of delay behavior and vulnerability to rejection sensitivity. Lower self-esteem and self-worth, less perceived control, and depressive tendencies appeared among individuals highly vulnerable to rejection sensitivity. Analyses of interactions between this high vulnerability in adulthood and delay time in preschool in the Stanford cohort showed that those with low delay time and high rejection

sensitivity were most likely to have lower coping, self-esteem, self-worth, and educational level and higher crack cocaine use. In the Bronx cohort, youth with low delay combined with high rejection sensitivity also had lower self-worth, lower peer acceptance, and higher aggression. Thus, although participants might report equal vulnerability, they might be able to modulate their responses differently depending on their ability to self-control and delay gratification.

Mischel suggested that intervention studies be done to determine what happens when differences in delay behavior are incorporated into educational interventions. He further stressed that an ability is not the same as a behavior pattern; the difference between having an ability and using that ability depends on the hot triggers and motivational conditions; e.g., whether or not a theory of entitlement intervenes. A large project across several groups and institutions is underway to examine brain, genetic, cognitive, and affective processes in a transgenerational study of high versus low delay, using the original Stanford participants, now in middle age, and their young children.

Delay behaviors involve brain systems that interact and are connected in mysterious and fascinating ways. At the psychological level, attention control, strategic self-distraction, and mental representation strategies enable cool system functions even in the face of hot stimuli. Rules for delay involve distraction, self-instruction, and cognitive transformation and abstraction. This phenomenon has implications for economic planning; savings, pensions, and healthcare plans; educational therapeutic interventions; diet adherence and medical regimens; long-term health and quality of life; and protective effects related to aging. The individuals in the Stanford cohort are now in their forties and fifties; this cohort thus provides an opportunity to explore systematically what happens as they move into old age.

Discussion and Comment

Workshop participants asked for more detail about how the studies described by Mischel were conducted. One asked what would have happened with the Stanford children if the cookie had been covered. Mischel noted that delay would have been much easier, as it was in conditions when children waited with the rewards covered (under the plate rather than on top of it). In response to other questions about repeat measurements, Mischel clarified that with delay measurements the first experience influences the second one. Thus, using the first measurement is best. He also noted that rewards other than food were used in some studies.

Current studies are attempting to tease out the specific role of response inhibition, attention deployment, moral inhibition, and neural reconstruction in delay behaviors. However, more performance or behavioral tasks for adults are needed. Followup studies in the Stanford cohort when those individuals were 32 years old relied on self-report and questionnaires. Dr. Angela Lee Duckworth described a measure she and her colleagues had developed for school-aged children and adolescents (see below). They are asked to choose one dollar today or two dollars in a week, and to make the temptation of the immediate payment more tempting, participants actually hold the dollar before they make their choice. Variations of this task are under development. Mischel also described a smoking cessation strategy he had used that relied on vivid imagery of a discounted outcome. How individuals use this strategy in their own delay behaviors can play out in different ways.

As noted by Dr. Richard Suzman, willpower is a big issue that cuts across the interests of BSR, the NIA, and the NIH, where investigators are interested not so much in telling people what they need to do as in offering strategies to help them do it. Advances in brain imaging and genetics can be combined with psychological studies to demystify willpower further. Combining resources, forming larger teams, and making use of archival data will be needed.

Economic Models

David Laibson, Ph.D., Harvard University

The way individuals think about discounting most likely changes depending on the time horizon. In experiments by Read and van Leeuwen (1998), individuals were asked to choose between fruit and chocolate in different temporal contexts. When they were asked to choose what they would like to receive the *following week*, most chose fruit. However, when they were asked to choose what they would receive today, most chose chocolate. In other studies by Read et al. (1999), individuals chose highbrow movie videos when they had to choose what they would watch 1 to 2 weeks later, but they chose lowbrow movies when they had to choose what they would watch that evening. Laibson summarized these findings by saying, “Tonight I want sugar-coated entertainment... next week I want things that are good for me.”

Discount rates measured experimentally tend to be higher when individuals have to make choices about short-term events (delay d) and lower when they make choices about longer term events (delay $d+\Delta$). In other words, the longer the delay, the smaller proportional inducement individuals need to wait for additional periods of time. For example, when undergraduates were asked if they would prefer X amount of dollars at delay d or Y amount of dollars at delay $d+\Delta$, they chose relatively impatiently when d was 0 and relatively patiently when d was one week. These effects were first described by Strotz et al. (1950s) and Herrnstein et al. (1960s) and have since been replicated in hundreds of studies (reviewed in Frederick et al. *J Econ Lit* 2002).

Yet these “money now versus money later” experiments may measure, and thus be confounded by, factors other than time preferences. Transaction cost, or the amount of effort to receive the reward at a later date, is one example. Another involves reliability effects, or how much the individual trusts that the experimenter will follow through with the reward in the future. Heuristics could also play a role in these effects, as could market interest rates or demand and framing effects. Moreover, these types of experiments do not measure intertemporal tradeoffs of consumption. In other words, individuals might not be sure they will consume (use) the money at the date they receive it, and these experiments do not consider the gap between receipt of dollars and consequent consumption of those dollars. Economists also do not consider that secondary reinforcements such as the symbolic representation of the reward might be as good as the reward itself. “Money now versus money later” experiments also do not account for intertemporal tradeoffs of utility. To address this problem, economists might use real goods such as time-dated food, drink, or experiences or rewards consumed in the laboratory instead of money. They also might use field data, moving away from abstract experiments that might not account for daily experience. However, both of these approaches are imperfect.

Laibson presented a theoretical framework for modeling intertemporal choice. This framework uses discount functions to model individuals’ devaluation of delayed rewards. Economists also consider the rate of decline in discount function, or how quickly the reward’s value diminishes

with delay, which is a measure of impatience. For small periods of delay, the rate of decline of the discount function is equivalent to the discount rate.

The most familiar or frequently used discount function is the exponential discount function, which implies that the discount rate does not change with delay period. Thus, the discount rate is the rate at which the discount function declines over time. Yet empirical evidence suggests that discount functions decline steeply in the short term but less so in the long term, pointing to the need for an alternatively defined discount function. Quasi-hyperbolic discounting (Phelps and Pollak 1968, Laibson 1997) distinguishes future events from present ones. This function reflects dynamic inconsistency in which preferences held at time t do not agree with those held at time $t+1$.

This framework can be applied to procrastination, for example. Work by Akerlof (1991) and by O'Donoghue and Rabin (1999) asked when individuals would exercise. The idea that an individual will exercise but not today, and tomorrow eventually becomes today, has been used to explain many self-defeating behaviors. Interventions might influence the behaviors, but a tension within individuals leads them to fail to follow through on their good intentions. Likewise, problems with adherence might result from individuals receiving a temporarily high payoff from exercise, then failing to maintain this routine as motivation declines. In terms of beliefs about the future, sophisticates know that their plans to be patient tomorrow will not work out, whereas naïve individuals mistakenly believe their plans will work out perfectly (Strotz 1957).

Daniel Benjamin, Ph.D., M.Sc., Cornell University

As has been discussed during this workshop, typical measures of time preference involve a binary choice between money now and money in a week. Discount rates measured with similar mechanisms have been shown to predict drug addiction (Kirby et al. 1999; Kirby and Petry 2004), cigarette smoking (Fuchs 1982; Bickel et al. 1999), excessive gambling (Petry and Casarella 1999), use of commitment savings devices (Ashraf et al. 2004), installment accounts or credit cards (Meier and Sprenger 2006), and rapid exhaustion of food stamps (Shapiro 2005). Likewise, typical measures of risk preference involve a choice between an amount of money for sure versus a 50–50 chance of winning money or getting nothing. Several studies have shown that hypothetical risk choices predict stock preferences, failure to hold insurance, being self-employed, smoking, drinking, switching jobs, and moving residences (Barsky et al. 1997; Guiso and Paiella 2001; Dohmen et al. 2005). These measures of time and risk preferences might correlate weakly with behavior, but they are predictive of behaviors in which economists are interested.

Dr. Daniel Benjamin discussed work relating cognition to these types of preferences, and he pointed out that although the work he would discuss does not involve hot-versus-cold systems, it does suggest the dual-system models discussed by Laibson and Mischel. In addition, these models predict that a person's willingness to accept delayed rewards is related to brain regions of executive function such as the PFC, and evidence suggests that measures of cognition are also related to these regions. For example, in a study of students at a private high school in Chile those who were more able to answer mathematical questions versus verbal questions were more likely to behave patiently and risk neutrally. One interpretation of these and the SAT data reported by Mischel could hold that the ability to delay gratification leads individuals to study

harder and engage in other activities leading to better test scores. However, one study found that mathematical ability measured in elementary school, but not the *change* in mathematical ability between elementary school and high school, is related to patient and risk-neutral behavior measured at the end of high school. This finding suggests not so much that patient individuals accumulate more ability over time but that higher cognitive ability results in more patience. Thus, cognition might be an economic phenotype of interest playing a role in the relationship between time and risk preferences. Indeed, cognition is related to economic choice as demonstrated by a study in which individuals' wealth and financial market participation increases with Armed Forces Qualifying Test decile (Benjamin et al. 2006), controlling for income and socioeconomic status.

Traditionally, economists have had difficulty finding datasets with both genetic and economic data because most genetic data are collected in health studies. However, several studies of genetics and preferences are underway. The Longitudinal Study of Aging Danish Twins measures education, income, housing, and financial assets among 3,000 twin pairs, although the economic factors are crudely measured. The Age, Gene/Environment Susceptibility–Reykjavik Study also includes some crude economic outcomes, and it employs a candidate gene approach in which 384 single nucleotide polymorphisms related to dopamine, serotonin, and cognition have been identified. The Boston Study, on the other hand, will involve whole genome analysis in the context of social preferences, discounting, risk aversion, cognitive function, occupation, income, and education. Benjamin also described preliminary work with two other existing datasets. Whether intermediate choices, such as career choice, are explored will depend on what these datasets have measured. It also should be noted that these studies might not control for use of psychoactive medications that might modulate cognitive effects.

Neuroeconomics of Aging

Trey Hedden, Ph.D., Massachusetts Institute of Technology

Several dopaminergic pathways in the brain contribute to complex behaviors. One pathway that contributes to reward and motivation extends from the ventral tegmental area, through the nucleus accumbens, and to the medial orbitofrontal cortex (mOFC). Another extends from the substantia nigra through the caudate and into the dorsolateral PFC (DLPFC), where it further extends through reciprocal connections with the ventrolateral PFC (VLPFC) and the parietal cortex. This pathway contributes to cognitive control, or the ability to modulate or regulate subsidiary processes underlying task-oriented goals. To understand economic behavior, one must look at how the contributions of the reward pathways in the ventral striatum interact or compete with those of the pathways involved in executive function and cognitive control.

Dr. Trey Hedden described a study of self-delusion in a setting where participants wish for a reward but cannot control whether they get it. In a first trial, college-aged, native English-speaking students with no experience with character-based language were presented with Korean characters. They judged whether each one was male or female. There was no right or wrong answer, as Korean characters are not classified as male or female, but participants received a nickel for every judgment that matched the majority opinion of those from previous tests. In a second trial, students then performed a task in the scanner, where a prediction was made about the gender of the next character before it was presented. The character then appeared, and the students made a second judgment. Participants received a large reward if their prediction was

correct. Trials fell into four categories based on participants' classifications in the first trial and their predictions and classifications in the second trial. The first two categories, consistency or inconsistency, measured the reliability or unreliability of a participant. The honest trial type referred to a trial in which participants making the second classification overcame predictions and were consistent with their first classifications. In a self-delusion trial type, however, the participants' second classification rather than their first matched the prediction. In this trial type, participants were influenced by the prediction and their desire for a reward associated with the prediction.

A straight contrast in neural activity between honest and self-delusion yielded nothing, but a behavioral index of self-delusion by inconsistency showed brain activation in predicted regions. Activation appeared in the mOFC as well as in an area on the medial surface in the posterior cingulate cortex, which has been associated with intertemporal choice. Strong activation was also observed bilaterally in the DLPFC and in the left lateral parietal cortex. Thus, pathways involved both in reward and in cognitive control were activated. It should be noted, however, that this activation was observed only if the extent of self-delusion to which each participant was susceptible was taken into account. The difference in activation correlated linearly with the ratio of self-delusion to inconsistency.

A strong decline in dopamine input is observed even among healthy older adults. By age 60, available dopamine declines by 50 to 60 percent in healthy adults compared with 80 to 90 percent in adults with Parkinson's disease. Moreover, available dopamine declines by 5 percent in the caudate and approximately 4 percent in the putamen (Erixon-Lindroth et al. *Psyc Res* 2005,138:1-12.). Thus, dopamine inputs decline in all regions of the reward and cognitive control pathways. It is possible that the relative influence of the two systems remains static despite the decline in dopamine input. However, it is also possible that a more complex cascade of effects occurs in older adults. Predictions about the effects of age on dopaminergic pathways are further complicated by variations in socioeconomic, experiential, personality, cognitive, neurological, and genetic factors. In terms of genetics and aging, for example, declines due to aging might be so great that they overcome smaller genetic differences in susceptibility. It is also possible that these small differences become even more important at later ages. Little work has been done in this area.

Hedden discussed a study examining the effects of varied discount rates and temporal sensitivities on intertemporal choice across ages. In this study, older adults displayed normative sensitivity but less discounting (Green et al. 1999). He also discussed work by Kable and Glimcher (2007), who assessed the subjective value of rewards in younger adults by obtaining an individual discount function for each participant, correlating the derived subjective value of each choice based on the individual discount function and correlating that subjective value with activity in the brain. In these studies, activation was observed in the mOFC, the posterior cingulate cortex, and the nucleus accumbens. No activity was observed in the cognitive control pathway, suggesting a single-process model for discounting where the choice between immediate and delayed gratification depends solely on an individual's discount rate. In contrast, studies by McClure et al. (*Science* 2006) suggest that relative activation in the reward and cognitive control systems affect this choice.

Hedden described work underway to further explore temporal discounting by looking more closely at processes involved in assessing options versus comparing them. This work will incorporate several areas of individual differences, including socioeconomic and experiential factors. Hedden also noted the need for more work examining brain-behavior correlations, both within and across subjects; brain-brain correlations based on structure-function and connectivity models; implementation of discount functions; potential process models; the influence of socioeconomic and experiential factors; and the impact of genetic factors on dopamine circuits.

Commentary

What Is Self-Control and How Do We Measure It?

Angela Lee Duckworth, Ph.D., M.Sc., University of Pennsylvania

Duckworth commented that economists and psychologists would benefit from a Rosetta Stone to help them understand each other. For example, self-control has been defined in many ways. Duckworth used the Baumeister definition of self-control: The regulation of impulses, emotions, attention, or behavior in the service of a valued goal. Impulsivity is the lack of self-control.

She described a study in which 140 eighth-grade students at a public school underwent several measurements including monetary choice and impulsivity questionnaires, self-report self-control scales, and delayed-choice tasks. This study did not control for parent income or education, although controlling for free and reduced-price lunch status did not change any findings. Although correlations among measures were not uniformly strong, they were uniformly positive and could provide some type of anchor. For example, a delayed-choice task does not correlate well with every measure, but it does correlate strongly, in a predictable fashion, with one or two of them.

Psychological measures fall into three categories: Neuropsychological tasks, delay-of-gratification tasks and questionnaires, and other questionnaires and rating scales. Duckworth et al. are conducting a meta-analysis to assess how robustly these different measures correlate in terms of self-control when more than one type of measure is used in a study. On the basis of preliminary results, correlations appear to be strongest among measures in a particular category but fairly weak across categories. Correlations between, for example, neuropsychological tasks and rating scales are positive but very low. It should be noted that correlation scores cannot exceed the reliability of the measures involved. Although reliability ratings among neuropsychological measures are typically high, the correlation among these measures is not.

The weak but positive correlations observed in these analyses might arise from several factors. Many neuropsychological and delay tasks are vulnerable to situational variants. Measures also vary in terms of methodology and error. In addition, self-control is a heterogeneous construct involving multiple, separate, and possibly interacting tendencies, and each measure might assess a different aspect of that construct. If these measures assess different pathways to the same behavior, then aggregating them might increase the signal-to-noise ratio with error and situational variance canceling out. However, aggregation might not be practical.

In the 1950s and 60s, self-control batteries tested such things as how long someone could hold up his or her leg. That tradition has faded because the batteries never achieved validity, but it

should be reconsidered. In addition, what underlies self-control and how this behavior is defined should be clarified. Frederick et al. (2002) proposed that self-control involves impulsivity, or spontaneous, unplanned behavior; compulsivity, or making and sticking to plans; and inhibition, or the ability to inhibit automatic responses to appetites and emotions. Whiteside and Lyman (2001) described impulsivity as related to urgency, lack of premeditation, lack of perseverance, and sensation seeking. Fellow and Farah (2005) described self-control in terms of future time perspective versus temporal discounting. Future studies will benefit by combining economic and personality measures, which can complement each other in many ways. Bowles et al. (2001) have suggested a cooperative research effort between psychologists, who have developed stable and predictive measures of personality and applied them to small samples, and economists, who usually analyze large datasets including psychological, demographic, and economic variables and whose measures are less susceptible to faking or bias.

Genetic Methods and Strategies

Robert Krueger, Ph.D., University of Minnesota

Krueger described efforts by himself and his colleagues to create new phenotypes using modern psychometric methods. They begin each wave by targeting midlevel domains and identifying unidimensional subfactors in each then use item response theory modeling to identify desirable items for each subfactor. Item response theory assumes that items measuring the range of a factor are not reliable overall but are reliable for a certain kind of person or trait. These efforts resulted in a model with 23 unidimensional scales, for a total of 415 items. The model is a formal confirmatory one in which the structure of the scales includes residual factors as well as general factors that saturate different domains.

On the basis of this model, three independent factors underlie the different concepts corresponding to three unrelated processes that lead to a series of different outcomes. The highest loaded factors are irresponsibility and problematic impulsivity, which might explain their link to downstream problems. The second factor includes aggressive outcomes; “being mean” can result in different outcomes. The third factor is the risk for drug problems, which may arise from the first factor. This model attempts to pull different literatures together into a bottom-up approach, which is important in psychology, where models are usually built top down. Krueger and his colleagues also have gathered a series of scales useful for measuring different concepts in a domain. Even so, the model might not explain how factors are manifest in other domains although there might be some correlations with electrophysiological measurements, which might have predictive validity in some tasks. Although the model is comprehensive, one can work online and use psychometric methods to choose the trait of most relevance.

Several short forms of this model have been developed. Thus, using it might not require much time unless a lot of detail is needed. Computerized adaptive testing uses modern psychometric models to better measure variations of individual differences, but it also can home in quickly on the level of latent factors in an individual. This type of process has been used in educational testing, where the computer begins in the middle of a range then adjusts based on the person’s responses, continually solving for the most likely trait score. Adaptive testing offers specificity for a large number of questions, but it also can be used for a shorter list of questions.

Computerized adaptive testing also overcomes time and space problems associated with gathering a level of detail that is psychologically important. Using this model in an interview

process might be possible, but talking to a person about his or her traits might distort findings. Thus, having subjects work individually online is ideal.

Proposed Strategies From a Neuroscience Perspective
Turhan Canli, Ph.D., Stony Brook University

The most striking aspect of the video clips presented by Mischel was the different strategies used by the children to delay the cookie reward. Although endophenotypes might be the best way to capture behavior, different strategies might be used to accomplish even a single task. Thus, high degree of variation is present even within a narrowly defined phenotype. The different strategies might represent a behavioral display of different neural circuits being activated, which most likely arise from genetic variations and environmental factors. Thus, future research should account not only for variability across tasks but for variability within them.

Investigators might also consider moving away from examining individual brain regions and think instead of networks. This shift will provide a more powerful and comprehensive way of thinking about behavior and of capturing variation. The shift also will have an impact on the types of analytical approaches to be used. One would still think about areas of activity, but now investigators would examine functional connectivity, for which many approaches, such as spectral equation modeling, are available. Focusing simply on group activity might miss all this activity, but capturing individual differences, even by self-report, will significantly link variation and activity across individuals with variation in brain activity.

Two strategies have been discussed in terms of connecting this type of work with examinations of genetic variation. One is the candidate gene approach in which one has a genetic polymorphism of interest and a reason to believe that it is involved in a specific behavior. This approach would then involve a careful analysis of how that gene might operate in the brain. However, the interpretation of such a study (that is, a genetic basis for an endophenotype) could be thorny. The other strategy moves in the opposite direction, from endophenotype to gene. Study participants perform a task while in a scanner, and investigators try to determine whether the individual differences in key brain regions of a network can be explained with respect to genetic variation. Assuming participants' DNA are available, DNA datasets are sorted according to where participants are in the endophenotype stratification and then examined for possible differences through pooled DNA analysis or gene microarrays. This approach would allow the discovery of new gene polymorphisms and provide a new set of candidates, but it also might yield many false positives.

Also discussed were polygenic traits, which are defined by many genes of small effect sizes. However, another interpretation has been proposed by Eli Hatchwell: It could be that a subset of individuals with a particular complex trait carries rare mutations explaining that trait. This possibility would not be captured in any of the current approaches exploring genetics and behavior. Having categorized these individuals, however, and having found candidate genes, one might have new ways to classify them.

Several imaging modalities are available to study behavior, neuroscience, and genetics. These modalities include MRI, perfusion imaging, white-matter diffusion imaging, measurement of gray and white matter volume, and PET. Integrating these modalities will offer the "biggest bang

for the buck.” An example is the Weinberger group’s exploration of structural and functional connectivity between the amygdala and the anterior cingulate and the genetic variations predicting the degree of connectivity. Focusing on networks and their dynamics, which will involve an integration of functional and structural datasets, will be useful.

Discussion

The psychometric story presented by Krueger is a compelling one. However, it is not clear what the implications would be in studies as broadly diverse as those reviewed by Duckworth where it is unlikely that all those measures, with adequate sample sizes, would be included. Krueger pointed out that the challenge is an exploratory one; a common scientific story is one of unanticipated discovery. Exploratory, extremely large-scale research that incorporates all 415 items would be ideal but not feasible. How to make psychometric models work statistically would be a challenge, and trying to condense all the information into something useful would be difficult because one would not have a strong theory or know where to look. On the other hand, large studies examining the predictive power of these scales for behavioral domains outside the ones in which they were collected might be more feasible. Such studies would increase the likelihood of having the right subset of participants in scanner studies. Laibson suggested that economists could provide neuroscientists with a list of 20 to 30 questions that neuroscientists could use to study the predictive power of the tools they have developed.

Workshop participants also discussed the rational consumer model and economists’ growing interest in refining predictions of individual decisionmaking. This new interest arises from many factors, including the improved ability to conduct empirical analysis in an age of computer technology and vast datasets with individual-level data. Traditionally, genetic and personality differences were lumped together as “unobserved heterogeneity” and dismissed by the rational consumer model. Economists have not attempted to develop a taxonomy of differences underlying the rational consumer model. Laibson noted that economists have a list of phenotypes, including years of schooling, wages, savings, and capital formation, but they still want to determine what personality measures are highly associated with those outcomes.

Workshop participants also discussed the role of politics in the rational consumer paradigm. For example, Singer discussed his experiences refuting a paper by Becker that relied on the rational man assumption. Singer and his colleagues had pointed out that this model had been rejected everywhere it had been tested. It was difficult to move from this theoretical framework to a point at which the level of individual data made reassessment necessary.

Although they thus far had not mentioned the Big Five (extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience), workshop participants did acknowledge it as the dominant paradigm in personality research, despite its faults.¹ The Big Five emerged from the desire to understand underlying factors and pulled together several personality measures. In so doing, this paradigm suggests that personality traits such as conscientiousness and neuroticism are predictors for occupational success, health, and other outcomes whereas extroversion and experience are not. Yet like the rational consumer model, the Big Five has ignored several dynamic processes and personality constructs. For example, it does

¹ See <http://www.uoregon.edu/~sanjay/bigfive.html> for more discussion about the Big Five.

not account for differences in motivation or agreeableness, nor does it account for extroversion outside of certain scales. Even so, workshop participants noted the importance of this attempt to create some type of taxonomy to explain personality differences. In addition, while some participants said that the Big Five is a coarse tool and not psychologically rich, others pointed out that the information it provides can be useful.

Several meta-analyses have attempted to identify which aspects of the Big Five predict economic outcomes, but these have not been comprehensive. In one, Heckman et al. (2001) noted initial concerns about structural validity when the model was first proposed. There are other models of personality differences, such as one proposed by Kloninger that looks at temperament and character with a focus on harm avoidance, reward dependence, and novelty seeking. Although these characteristics might help to describe how one approaches financial decisionmaking, the model does have some problems in terms of structural validity. Likewise, the California Personality Inventory (Goff) and the Hogan Personality Inventory deliberately exclude items that do not link to occupational performance. However, these models have some predictive ability, which is of more interest to economists.

Again, applying genetic analysis to economic phenotypes will benefit from an integration of methods. For example, Duckworth pointed out strategies for using quantitative genetic, neurobiological, and possibly molecular genetic methods to further explore findings from these models, no matter how coarse those findings might be. Benjamin also described an ongoing project of the HRS to understand the range of cognitive ability and to measure, in a short amount of time, several economic variables such as preferences, numeracy, and behaviors in long-term care. Investigators on this project intend to use these data as part of a pilot study to identify correlations, which might guide decisions about content in future HRS waves.

CURRENT STATE OF INDIVIDUAL DIFFERENCES RESEARCH: RISK AND LOSS AVERSION

Risk Taking and Loss Aversion

Elke Weber, Ph.D., Columbia University

Risk taking has been modeled traditionally in economics by the Expected Utility Theory, where risk taking is described by the curvature of a utility function that is derived from individuals' choices between risky prospects. In finance, it is described by risk-return models such as the Capital Asset Pricing Model, which assumes that risk taking involves a conflict between greed and fear. Both models assume that risk is an invariant attribute of a choice alternative and that individuals differ only by risk attitudes or risk tolerance. Even though this is not implied by economic models, risk attitudes are often interpreted as a personality trait, measured by psychometric scales (Kogan and Wallach 1962), and used as selection criteria in several ways, such as in hiring decisions or in client-advisor pairings. Yet interpreting risk as a personality trait is problematic. Personality traits should be invariant, or at least predictably variant across situations, but risk taking by the same individual varies across contexts and situations. This can be seen, for example, in a situation where a manager is risk neutral with company money but risk averse in her personal financial decisions, or where a rock climber takes many recreational risks but is anxious about missing flights. Situational variance in risk taking has been observed in a

systematic comparison of risk taking in multiple domains (financial, health, recreational, ethical, or social decisions).

Dr. Elke Weber and colleagues have collected a large number of hypothetical risky scenarios for a population extending from average college students to adults, within several domains, and they have found five domains in which items cluster: Finance, health, ethics, recreation, and social. Their scale, called DOSPERT for Domain-Specific Risk-Taking (Weber et al. *J Beh Dec Making* 2002), contains eight items within each domain, for a total of 40 items. Subscales can be aggregated for a total score regarding risk attitudes, and the subscale correlations with total scores are good. Even in the best of situations, however, intercorrelation among risk taking in different domains is not high. For example, the correlation of social risk taking scores with other subscales is fairly low. DOSPERT Scale scores, even though based on self-reports, are a fair proxy of real-world risk taking, as demonstrated in a study by Hanoch et al. (*Psychol Sci* 2006) that tested known risk takers in several domains and showed that their DOSPERT Scale scores discriminated them from non-risk takers in the relevant domain. Although self-reported risk taking may differ somewhat from actual risk taking, the DOSPERT Scale appears to be useful.

Expected Utility Theory, on which traditional economic models are based, models risk taking with a single parameter and does not account for situational differences in risk taking. Some behavioral models have tried to add other determinants. Prospect Theory has added loss aversion and probability weighting, and Weber and Milliman (*Management Sci* 1997) have incorporated differences in perceptions of risk and benefit. Weber et al. have also used the DOSPERT Scale to assess why individuals take risks in some situations but not others and have found that it is not so much the differences in risk attitude but in perceived benefits and in perceived risks that determine how risk taking varies.

Perceived riskiness can vary based on expected outcome volatility and reference points. It is also determined by how familiar an individual is with the risk and how much control that individual thinks he or she has. Weber et al. (*Risk Analysis* 2005) found, for example, that observed home bias effects in investing were mediated by differences in perceived riskiness. Weber et al. (*J Beh Dec Making* 2002) also have found that women who appear to be more risk averse than men in most domains except for the social one have much greater perceptions of the risks than men in those domains where they appear risk averse. Emotions also play a role in perceived riskiness, particularly dread and fear (Loewenstein et al. 2001). Models of risk taking must distinguish between these elements of perception, which focus on an evaluation of outcomes and probabilities, and motivational elements, which focus on the effect of perceived risk (is it exciting or scary?) and which might have a biological basis, most likely based on optimal arousal set points. If such a biological construct exists, it is most likely a relatively stable trait, but it cannot be found if all the elements of risk taking (perceptions and attitudes) are combined into a single parameter. Weber et al. have defined a tradeoff coefficient that addresses how much benefit must be added to increase one's willingness to take a risk as it is perceived, and this coefficient appears to be relatively constant across domains.

Some effects, such as those added in Prospect Theory, have been attributed to "risk attitudes" (in the Expected Utility Theory sense) when in fact they are not attitudinal factors. On the basis of their influence and the factors involved in risk perception, loss aversion and probability weighting can affect risk taking to different degrees in different situations, and they may explain

the low correlations observed among measures of risk taking. The term “probability weighting” covers many effects. One is the certainty effect (Kahneman and Tversky 1979). Another related one is the tendency to overweigh small probabilities. For example, even though individuals tend to be risk averse with respect to gains, they overweigh the small probability of winning; for example, when they play the lottery. Likewise, individuals might be risk-seekers with respect to losses, but they still buy insurance. Advertisements for the lottery or insurance further inflate the small probabilities of adverse events by playing on individuals’ emotions. When it comes to probability weighting, it is important to know how people know or have learned about small probability (rare) events, either from description (where they are given the probabilities numerically or graphically) or from (personal) experience (where they learn the probabilities from the feedback of making repeated decisions). Individuals tend to overweight rare events when they have to make decisions based on description, but they tend to underweight events when making decisions based on personal experience (Weber et al. *Psych Rev* 2004). In decisions from experience, recent experience gets a large(r) weight. For example, when a terrorist attack occurs, people tend to overweight the probability of that event occurring again, but as time progresses with no more attacks, these same people start to underweight the probability. The way in which individuals learn small probabilities determines how they will weight them.

Distinctions also must be made between static risks and dynamic risks when assessing risk taking. Most traditional measures of risk taking involve static situations, and situations where individuals are asked to make decisions in a cold state. In the real world, however, decisions are ongoing and dynamic and often hot. For example, a person does not decide to binge drink at the beginning of an evening but makes successive decisions to have another drink as the evening progresses. Therefore, laboratory analogs of dynamic, sequential risk taking are needed. One example is the Balloon Analogy Risk Taking model (BART, Wallsten et al. 2005), where individuals receive more money the larger their balloon becomes. In such a situation, the subject would want to make his or her balloon as large as possible without popping it. Another example is the Columbia Card Task (CCT, Figner et al. 2007), in which the subject is told how many of 36 cards are good cards, how much money those cards are worth, how many are bad cards, and how much money could be lost with those cards. The task involves turning over as many cards as desired, with good cards earning additional money, but ends once a person turns over a bad card. The CCT has both hot and cold versions validated by galvanic skin-response measures, and it can assess cognitive complexity as the number of good cards versus bad cards and the amount of gains and losses vary. This task has been shown to replicate the excessive risk taking observed among male adolescents and does so only in the hot version.

Like probability weighting, loss aversion is another factor to explain risk taking that has been added to Prospect Theory. Weber and Johnson (2006) have proposed a theoretical framework in which preferences are constructed as memory. This framework leverages what is known about output interference in memory with the goal of providing a unifying account of seemingly disparate phenomena such as loss aversion, temporal discounting, and default effects. The framework includes a common mechanism that can predict common individual differences as well as common age or life span effects. A cornerstone of the framework is Query Theory. According to this theory, a person decomposes valuation questions into queries to memory and executes these component queries sequentially. The query order depends on the type of valuation question. The first query produces a much richer representation, and potentially relevant

information in subsequent queries is inhibited. Thus, path dependence is a factor; i.e., it matters which query gets asked first.

An example can be seen in an endowment effect study by Johnson et al. (*JEP:LMC* 2007), where the amount that a person is willing to pay to buy a mug is much lower than the amount the same person would want to sell it. In this study, participants queried value-decreasing aspects of the mug first when asked how much they would pay for the mug, resulting in more such evidence, whereas they queried value-increasing aspects first when asked how much they would ask for the mug. The difference in query order resulted in differences in the balance of evidence, which in turn mediated differences between buying and selling prices, called the endowment effect. The endowment effect disappeared when participants were prompted to generate queries in an opposite or “unnatural” order; for example, when sellers were asked to focus on value-decreasing aspects first.

If loss aversion results from preference construction, then Query Theory would predict that loss aversion increases with age. Older adults are more affected by fan effects (Cohen 1990; Gerard et al. 1991) and less able to avoid interference on Stroop and short-term memory tasks (Hedden and Park 2001; Spieler et al. 1996). They show less ability in directed forgetting tasks (Zacks et al. 1996) and worse part-list cueing effects (Marsh et al. 2004). In addition, fluid intelligence has been shown to decline among older adults, suggesting that memory interference might play a larger role for them, resulting in greater loss aversion.

In a study by Gaechter et al. (2007), 347 owners of a popular German car underwent personal interviews in which they were presented with several different measures of loss aversion, and information from these interviews was analyzed as a function of their age, education, income, and other factors. One aspect of this study focused on buying versus selling price. Participants were given Matchbox cars resembling the car they had bought before and asked how much they would pay for the car. At the end of the interview, they were asked what price they would require to sell the car. The coefficient of loss aversion could be assessed based on the ratio of selling and buying price. Participants also were given the option of buying cars with five different attributes, and again, buying and selling processes could be assessed to infer loss aversion. The correlation between loss aversion for risky situations and one for situations of no risk was 0.59. However, the correlations between the loss aversion coefficients for the five car attributes were low. Query Theory would predict that loss aversion varies based on expertise with or knowledge of an attribute. Indeed, the loss aversion coefficient was 2.25 for people who did not know anything about a particular attribute, but it decreased to 1 (i.e., no loss aversion) among experts. The importance of an attribute also had an effect. Loss aversion increased when attributes were perceived as important. The most important drivers of loss aversion appeared to be age, knowledge, and importance. Education and income also affected loss aversion. More educated individuals were less averse, most likely because they were more analytical. On the other hand, individuals with more income were more loss averse, which is puzzling because, as pointed out by Laibson, loss aversion can lead to poverty. Recent analyses also suggest that affect, as defined by anticipated regret, can reduce income.

Discussion and Comment

Suzman observed that like Weber, David Cutler et al. have raised questions about discrepancies between hypothetical risk scenarios and real-world behavior when no intercorrelations among health risk factors were found in a national population. In addition, he noted work showing a large discrepancy between risk perceptions and actual risk.

In response to questions from workshop participants, Weber clarified that she and her colleagues communicated what they meant by perceived risk by asking participants to judge how risky they thought an activity was on a scale from 1 to 7. At other times they gave participants examples that anchored the rating scale end points or had them make ordinal judgments. In another study of risky investment decisions (Weber et al. *Risk Analysis* 2005) they asked respondents to estimate expected returns, the volatility of returns, expected risk, and how anxious they would be after investing in an option before finding out their returns. Investment decisions were predicted by expected returns and expected risk (which correlated with worry), and predicted volatility was not a predictor of choice.

Skill or perceived skill can be a factor in perceptions of riskiness of some behavior. In some cases activities might be considered risky but not to those who engage in those activities and consider themselves experts. As discussed by Weber, dread and controllability are also factors. Social network or bubble effects can also affect perceptions of risk.

Workshop participants also clarified that in the CCT, group differences among adolescent males were seen only in the dynamic context. This group is known to have a particularly strong coding of rewards, though somehow this only occurs in the dynamic, hot version of the game. Weber's collaborator Figner and colleagues are now using this task to study methadone addicts to determine whether their behavior is similar to that of adolescent males. The CCT can look not only at risk taking but also at the complexity of how information is used. A version of BART has been adopted in which the dynamic aspect has been removed.

Biological Approaches to Risk Taking and Impulsivity

James Blair, Ph.D., National Institute of Mental Health

The brain involves a wide array of systems, and the interference of any one system could impede an individual's ability to generate wealth; but factors such as intelligence quotient or mathematical skill might offer more direct linear correlation with wealth-generating potential than a factor like episodic memory. Studies focused on systems might be more relevant to aging and decisionmaking than to economics, and they could tie in with genetic analyses. Systems are also problematic with regard to psychological constructs such as impulsivity or empathy because they involve different functional or cognitive processes. For example, autism and psychopathy are both classified as empathy disorders, but they do not share a common impairment and are vastly different disorders. Dr. James Blair suggested that models of intertemporal choice and decisionmaking based on expected value could improve the field of macroeconomics, but he feels that one does not need to understand the systems for this to take place so long as individuals are well characterized.

As with other traits, impulsivity involves a wide variety of systems that, when dysfunctional, increase the probability of risk taking and impulsive behavior. These systems include the dorsolateral and parietal cortices involved in attentional control (Desimone and Duncan 1995), the inferior frontal cortex in response modulation (Luo et al. 2006), the ventromedial PFC (VMPFC) in the representation of outcome and the detection of contingency change (Budhani et al. 2007), and the nucleus accumbens in the appropriate representation of future awards (Winstanley et al. 2006). A substantial amount of literature, including animal studies, has implicated the VMPFC in the representation of outcome information (for example, Schoenbaum and Roesch 2005; Tremblay and Schultz 1999), with greater activity observed with a greater reward (Blair et al. 2006; Kuhnen and Knutson 2005). Moreover, this region shows activity both in the anticipation and the receipt of that reward (Knutson et al. 2005), although this issue is still a matter of debate (Knutson et al. 2001). The VMPFC receives outcome information from several structures, including the amygdala, the insula, and the nucleus accumbens. The amygdala allows for reinforcement learning by distinguishing good reinforcement stimuli from bad and by feeding this information into the VMPFC. Communication between the VMPFC and the amygdala is an important system in impulsivity.

Two approaches have been employed to determine whether the VMPFC is involved in the representation of reinforcement information or in the decisionmaking processes that allows one to make a choice. One approach measures the activity in this region in response to more choices (Marsh et al. *NeuroImage* 2007), whereas the other presents two choices but varies the interreinforcement distance (Blair et al. *J Neurosci* 2006). If the VMPFC is involved only in coding reinforcement information, then how much information is obtained and how much is available in the environment will be of interest. On the other hand, if this region is involved in decisionmaking, then greater activity is expected as the number of choices increases and as the decision becomes more difficult because of reduced interreinforcement. In studies where participants were asked to choose the lesser of two losing options, the winning option versus the losing one, or the best of two winning options, the VMPFC did not respond to interreinforcement distance. However, it was activated by how many points the participants received and how many were cumulatively available. The dorsal anterior cingulate, on the other hand, was activated in response to interreinforcement differences. Thus, the VMPFC is important for coding reinforcement information.

Psychopathy is a rarified form of antisocial personality disorder, which Blair noted is a problematic diagnosis that is used more clinically in the United States. Psychopathy involves a lack of remorse and attachment and a disruption of the formation of stimulus-reinforcement associations, particularly those involving punishment. Patients with psychopathy are more likely to engage in activities that harm themselves or others, and they are less likely to be guided away from threats or from objects associated with harm to others. In addition, they show impaired decisionmaking related to stimulus-punishment choices. Learning to avoid threats involves socialization and anxiety about pain, fear, and sadness. Yet in one study (Marsh et al. submitted), patients with psychopathy showed reduced responses to fearful facial expressions compared with healthy patients or patients with attention hyperactivity deficit disorder (ADHD). Patients with ADHD were included in these studies because children with psychopathic tendencies often meet the criteria for this disorder. Moreover, connectivity between the VMPFC and the amygdala is reduced in individuals with psychopathy.

The VMPFC is important not only for coding reinforcement information but also for responding to an outcome different than one that was anticipated. If participants performed a task and expected a reward but did not receive it, activity was suppressed in the mOFC and VMPFC and augmented in the dorsomedial PFC and the right inferior frontal gyrus and insula (Budhani et al. *NeuroImage* 2007). However, suppression of the VMPFC was not observed in children with psychopathic tendencies.

Saver and Damasio (1991) have observed what they call “acquired sociopathy” in patients with VMPFC lesions, but Stone et al. disagree with this characterization. This group observes that patients with VMPFC lesions acquire gullibility because they are cheated, often by individuals with developmental psychopathy, but are unable to see the problem. The whole system for representing outcome is impaired. In patients with psychopathy, however, outcomes and circumstances are accurately represented, but the reinforcement is not in place. This may have some implications for aging and economic decisionmaking.

Knutson et al. (*Neuron* 2006) conducted a study where participants were presented with a product and the price and asked to decide whether to purchase the product. Greater activity was observed in the nucleus accumbens and the PFC when participants decided to purchase the item but in the insula when participants decided not to purchase it. In another study (*Nature Neurosci* 2007), positive affect was associated with reward cues. However, older adults were less upset by negative cues, possibly because of differences in coding of loss. Less recruitment was observed in the anterior insula and the caudate in the anticipation of loss or nonloss in these participants. Both younger and older adults experienced increased insula activation in response to increased reward. However, increased insula activity in response to punishment cues was observed in younger adults but not in older ones.

The work discussed by Blair points to the use of many systems in impulsivity; the need for more specific mental health categorizations, particularly with respect to psychopathy; and the role of the VMPFC in decisionmaking and possibly in aging and in economic decisionmaking. All the tasks described rely on the communication between the amygdala and the VMPFC, and individuals perform better on short-form tasks than on long-form face tasks, as expected. Blair pointed out that many worry about the short form, but he worries more about the long forms because they do not differentiate between neutral and fearful faces, whereas the short forms do.

Discussion and Comment

Although patients with psychopathy are said to make odd decisions because of impaired decisionmaking with regard to punishment, economists might argue that these individuals express different preferences as opposed to making mistakes. In some instances, individuals with psychopathy were observed to make better choices because they were more dispassionate. Patients with psychopathy may perform normally in situations that do not rely on reinforcement learning, but they may not be able to optimize decisionmaking in situations involving interreinforcement distance. Economists might argue that loss aversion disables individuals from making good choices, whereas someone with psychopathy who is oblivious to the loss might make better choices. However, Blair does not know of any data supporting this argument.

Similar psychopathy-related impairments are seen in children and adults, although they differ in the level of VMPFC impairment as observed in studies in the United Kingdom. Work by several groups suggests that children with psychopathic tendencies are more likely to develop psychopathy in adulthood. Some data suggest that emotional dysfunction remains constant throughout the lifespan but that antisocial behavior declines in individuals older than 40 years. What happens in older age is not known.

Discussion focused on the Knutson studies and their implications for aging. Workshop participants expressed concern that the cue task in Knutson's studies could be relatively resistant to cohort effects but not to psychiatric conditions such as depression. However, participants were screened for these conditions. Performance on behavioral tasks in the Knutson studies was related to affective response to the task. If older adults did not lose when they thought they would, they did not exhibit a reversal in affective state. However, they responded as young people did if they did not receive a reward they had anticipated, suggesting the need to decompose which piece of reinforcement response is broken or changed. The data presented by Blair clearly show that the VMPFC codes loss and reward, and it is expected that age-related changes could be observed.

In many studies of intertemporal choice, the loss domain is somewhat problematic because participants often choose between two rewards. A more sensitive task might involve a loss aspect to capture age-related differences and where they are, even though older adults show less sensitivity to loss and even appear to guard against loss information. There is some evidence that older people immediately focus on negative cues then look away. In terms of the systems described by Blair, negative stimuli might be coded by the amygdala but not communicated forward to the insula and other structures. Likewise, in patients with psychopathy, the amygdala responds to threat and aversive material, but the VMPFC does not "hear" the amygdala. If that is the case, then loss might not be the correct term to use. Blair noted that the term "loss aversion" primes someone for the loss. Thus, care should be taken in how labels are defined.

With respect to economic behavior, it was suggested that one could define psychopathy not as a binary construct but as a spectrum or continuous range, correlating items such as lack of empathy or lack of sensitivity to loss. Such a spectrum could indicate a dimension of variability. Blair expressed concern about large correlative studies because they often assume that one variable determines a range when, in fact, many variables are more likely to have different effects at different parts of the scale. For example, psychopathy measures assign a score from 0 to 40. Those scoring above 30 are defined as patients with psychopathy, whereas those with scores in the low 20s or below are classified as normal. Yet impairments are observed in people scoring in the middle range although they differ from those observed in people scoring above 30. That and the selective effects of other factors across the range would cause problems with such a spectrum. For example, a psychopathy study published in *Nature Neuroscience*, which was based on extreme-group design, presented conclusions that were opposite from those in the original submission, which were based on a correlative design. This could be related to personality. For example, Krueger has observed two distinct personality profiles associated with a high psychopathy score: Impaired anxiety and impulsive antisociality. Blair noted, however, that for him personality is not a clear concept, and translating differences in self-concepts would be related to brain systems.

Commentary

Synthesizing Approaches From Economics, Psychology, and Neuroscience

Robert Krueger, Ph.D., University of Minnesota

Understanding economic phenotypes will mean trying to understand the structural considerations and the tools used. Weber, Blair, and Krueger work in the same discipline but approach individual psychological differences in different ways and from the vantage point of different diseases. On the basis of Weber's work, these models will have to be built within the context of risk, whereas models incorporating Blair's work must consider impacts on brain systems, which will be important in developing phenotypes. These approaches and others should be synthesized, and the level of analysis that will be most relevant and useful in building economic models should be determined.

Economists, psychologists, and neuroscientists can engage in an empirical enterprise in which data are collected from a large population on individual differences in behaviors most important to economists. Psychologists could contribute to the exercise by determining which individual differences are most important to measure. Another approach, which would use smaller sample sizes, would involve building from the brain systems up to the economic phenomena. Either way, what results is something interesting and synthetic between the two fields.

Turhan Canli, Ph.D., Stony Brook University

Better models and theories are needed to increase understanding of economic behavioral phenotypes relevant to aging. These models and theories might exist, but they exist in several domains. Models based on systems and networks and the way brain regions communicate are found in the neurosciences. Models such as Query Theory and Prospect Theory are found in economics. In aging research, there are models such as Carstensen's Socioemotional Selectivity Theory. More opportunities like this workshop in which neuroscientists, economists, psychologists, and aging researchers learn from each other are needed. Most useful would be a regular format that is available to a larger group of people. Workshops also will continue to be useful. These educational opportunities, which will expose researchers to fields outside their own, can serve to optimize collaborative efforts. Other types of support are needed as well. Support to assist researchers in traveling to and learning in each other's laboratories as well as for high-risk, exploratory research projects that have little preliminary data will be needed.

All these efforts should have as their goal the development of models that are relevant to the real world. As people from various disciplines work together to develop new paradigms, they should consider the instrumental approaches already available and the paradigms commonly used and assess whether these are the best to use to examine real-world economic behavior. For example, Weber's models for decisionmaking could consider hot versus cold conditions with the assistance of neuroimaging techniques. At present, many studies of behavior rely too much on self-report data; this approach should be supplemented with objective behavioral data. Whether any of this is predictive of behavior in the real world will depend on the level of analysis. Understanding biological mechanisms will inform economic theories in a way that taking cheek swabs in the future to assess genetic makeup will not be necessary, because the theories are

constrained biologically. In other words, biology will be relevant in building the house but not in day-to-day use.

Paradigms will need to be developed for large studies versus small ones. What is required for imaging a small number of individuals will differ from what is required for a large online survey of thousands of individuals. Both will be needed to understand biology, particularly genetics. One approach will allow questions about mechanism, while the other will help to eliminate or reduce false positives. All these efforts will foster the development of a new field to answer questions about economics, genetics, and aging, and enough pieces exist already to make such an effort feasible.

Discussion

Because economists have traditionally sought parsimony in describing behaviors, their models tend to provide an overly general view. Economists will most likely need highly specific models for some applications and general models for others, but the traditional view does not provide an option for more specificity. They will therefore benefit from working with psychologists, who have traditionally focused on detail and maximum accuracy in their descriptions of behavior and can therefore provide context specificity and, ultimately, flexibility. On the other hand, psychologists will have to become mathematically adept if they want to aid in changing or replacing economic theories. Both economists and psychologists will have to consider developmental aspects as they define economic phenotypes, as traits might change throughout the life course with some regularity. New models will have to go beyond early life, adulthood, and older adulthood. For example, late adolescence differs from early childhood. Yet another nuance involves differences between mean-level changes and rank order changes as described by the Roberts group at the University of Illinois at Urbana-Champaign.

Top-down approaches will be necessary for building economic phenotypes. Workshop participants agreed on the need for collaboration among economists, psychologists, and neuroscientists to produce an instrument examining economic phenotype, personality attributes, and imaging data. This instrument can aid researchers in identifying sources of psychological and neural variation. However, how traits are described and grouped must be considered. For example, Blair's work starts with an identified behavioral condition and attempts to find neural associations for that behavior. As discussed during Blair's presentation on psychopathy, full characterizations of neural and functional systems will likely lead to a readjustment of conditions based on behavioral sequelae as opposed to grouping behaviors under one umbrella. From another perspective, however, patients with psychopathy tend to exhibit two behaviors: Unusual lack of anxiety and impulsive antisocial tendencies. Because different starting points might lead to different results or views, economists must determine which behaviors will be most useful in future models.

Bottom-up approaches also will be needed, and care must be taken in how these approaches are constructed. Building economic phenotypes will require a shift in thinking from single genes to biological systems that are associated with behavior. For example, heritability is high for intelligence, but although genes have been found for subcomponents of intelligence, attempts to find a gene for intelligence itself have failed. Genes encode proteins that act through systems, and most traits are polygenic. New approaches must start with candidate neurobehaviors and the

genes involved, then work up to behavior by incorporating contextual and environmental factors that affect how genes are expressed and how neurobehaviors are manifested. This will involve a combination of candidate gene and whole genome analyses. Polygeny and pleiotropy must also be considered. There was some debate about the effects of situational context on how activation of brain areas translates to behavior and outcomes. Some participants argued that some outcomes are inevitably linked to certain behaviors. For example, someone who is fearless will eventually get into trouble and go to prison. Others argued that situational context plays a large role. For example, individuals with VMPFC lesions, who are more prone to temper tantrums, might be viewed as more threatening depending on the circumstances they are in.

Several datasets are available for economists, psychologists, and neuroscientists to use. The NIA participated in a large-scale experiment in which older individuals participated in an online survey about their decisions with respect to Medicare Part D. This experiment was done in the context of the HRS, which also collects data on cognitive function. The results therefore might point to potential relationships between these decisions and cognitive ability. The HRS also has asked participants about their perceived probability of living to a certain age, becoming disabled, or living in a nursing home. In addition, DNA samples have been collected. Most data are available online, although some components involving restricted information require special registration and permissions. Approximately 1,200 to 1,500 papers have used HRS data, and seminars are available to help researchers access the data. Other resources include the English Longitudinal Study of Ageing, which includes psychosocial measures and DNA samples, and the Wisconsin Longitudinal Study, which includes DNA samples. Researchers must apply for permission to access DNA samples from the English Longitudinal Study of Ageing.

Workshop participants discussed the need for predictive validity. Some worried that most personality studies so far had been correlative rather than predictive, whereas others pointed out examples such as a meta-analysis of outcomes predicted by personality (Roberts et al. in press). Suzman commented that predictions might be made more meaningful if they incorporated institutional structure, situation, and other factors. He encouraged more grant applications to the BSR to support longitudinal studies. Predictive value will be aided by a clear definition of what constitutes a good decision versus a bad one as well as by an understanding of intraindividual differences in decisionmaking. For example, a person might not take away from a college fund, but that same person might amass a large amount of credit card debt. In another example, investigators using HRS data found several differences in wealth among people with similar income levels. These differences might be explained partly by the passive response of most to the institutional environment in which they are asked to save. Those working for a company that offers strong savings plans are more apt to save than those working for companies that offer few or no plans.

Participants also expressed concerns about increased numbers of false positives as more information is gathered. A Bayesian method using other kinds of data to construct rational priors might provide a way of calculating statistical thresholds, which in turn will strengthen the results researchers observe but reduce the risk for false positives.

Individuals' beliefs about themselves present another challenge in modeling economic phenotypes and applying them to an older population. For example, some individuals will account for the possibility of dementia as they plan for the long term, whereas others cannot

imagine being unable to make decisions. These types of differences are relevant both developmentally and in terms of self-control problems discussed by Laibson. Another challenge is presented by changes in the types of decisions older individuals must make. There was a time when someone retired and received a pension check until he or she died. Now, older adults are more likely to have an individual retirement account, and they make financial decisions for several years until they reach a stage where others must make decisions for them. More models and theories about preferences among extremely older adults will be needed to guide those who make decisions for these individuals.

The ability to fake personality or preference is another challenge, which might explain why economists emphasize constructs of intelligence. For example, a histogram based on National Longitudinal Survey of Youth data shows a bump two standard deviations below the mean. This bump represents the “wise guys” who tried to see how low they could score. The ability to identify genotypes associated with personality traits might alleviate this problem. Some participants noted that a surprising number of individuals describe how they really are, no matter what the stakes are. However, others expressed concern that developing economic policies based on personality traits might provide a stronger incentive for faking.

Workshop participants discussed the effects of new economic paradigms based on genetic analyses. They acknowledged the need to develop new paradigms and to discard old ones that are not useful, but they also understood the level of discomfort many would feel as new paradigms are developed. Suzman pointed out that basing models on personality prediction could be problematic because of the complex ways in which personality traits are organized. Unless behaviors are embedded in classifications such as education, economists might miss the relationships they want to find. Economists also must decide, for example, whether they would construct macroeconomic models based on a young market, as opposed to an old one, or based on an average across the entire lifespan.

Participants also expressed the desire to use new models to create interventions that could help individuals with decisionmaking. For example, if certain personality traits are associated with a risk for negative economic outcomes, policies could be developed and individuals counseled to address those risks. Workshop participants envisioned the ability to provide individuals with advisory resources to make individual decisions rather than giving a risk-aversion questionnaire or measuring discounting or impatience. However, some participants also expressed concern that policymakers would go too far and actually try to force changes in personality or preferences, and they questioned the role of the state. Other participants speculated that economic models based on psychology and genetics might aid in the creation of a Federal regulatory structure that allows private agents to offer services based on different preferences. How such a structure is created is currently under debate. Yet other participants commented that new economic models could be used to develop policy that accounts for behaviors and thus creates a more beneficial environment as opposed to trying to change economic behaviors. New models could also provide information on genetic differences that affect how individuals respond to interactions.

GENERAL DISCUSSION

Although the workshop is entitled “Refining Economic Phenotypes for Genetic Analysis,” future efforts should not be restricted to this sequence. Genetic analysis should be done with whatever

phenotypes are defined while economic phenotypes continue to be refined. In addition, defining an economic phenotype is not a trivial endeavor. Measures of economic behavior range from microlevel measurements of game-playing to macrolevel behaviors such as wealth accumulation. Endophenotypes, or specific behaviors in a laboratory experiment at a particular time, can be measured precisely. However, these behaviors can be influenced by different factors, and measures must be aggregated to reduce the noise from individual experiments. How to aggregate these measures must still be defined, and consensus will be needed on the best variables to use. Which personality variables will be most important and how genetic factors will play a role are not clear. Although the workshop focused on intertemporal choice and risk and loss aversion, there is a long list of macrolevel and microlevel behaviors for which more information is needed. In addition, the enormous overlap between economic and health behaviors as well as the mental representation associated with world view, religion, ideology, and long-range goals should not be ignored.

As discussed throughout the workshop, the incorporation of genetics into advice giving, using individual genetic tests, and cheek swabs to predict individual economic behavior is not feasible or desired. Workshop participants envisioned the development of concepts based on the genotypes of small subsets of individuals and the use of these concepts as foundations for higher order structures. Genetics would be inherent in the structure, but they would not be used in the day to day. Thus, genetics can play a role in the reimagining of economics much as neurology and behavioral science have.

Participants noted the large amount of mutual respect shown at the workshop as well as the complementarity between economics and psychology. This type of respect will be critical to future collaborations among economists, psychologists, and neuroscientists. Participants recognized that economists rely on parsimony and that their existing framework has been useful in policy. However, economists will have to be flexible and consider alternatives to their paradigms. They will have to identify and create new measurements to predict variation, and they will have to develop new theories. Economists should not abandon all paradigms, but they should be flexible, collaborate with noneconomists, and test ideas empirically. They also should take advantage of statistical tools used by psychologists. Likewise, psychologists can learn from economists. Like economists, they are interested in real-world data, and economists have constructed tools to analyze these data and infer causality. Economists also have tools to model the effects of foresight and awareness on predictions of behavior.

There was some debate about methodological issues and analytic problems involved with incorporating genes and environment into economic phenotypes. Some participants suggested data mining as a starting point and replicating tests with other datasets to weed out false positives. However, related smaller scale studies that explore, in depth, the individual differences within a particular domain also could be useful.

A great deal is known about the neurological and cognitive underpinnings of aging including memory, cognitive control, speed of processing, and changes in connectivity and it is likely that these changes will have profound effects on the relationship between cognition and economic behavior. It is not clear whether or to what degree personality factors will continue to affect economic behavior in older adulthood. For example, work is still needed to determine whether these variables will be overcome by cognitive declines and to assess how cognition and

personality interact at these stages. Differences related to age-associated diseases such as Parkinson's or Alzheimer's versus differences associated with healthy aging also should be explored. Patients with these diseases will encounter different economic decisions, and in time, their decisions will be made for them by others. Thus, caregiver issues should be explored as well. Measurements to identify adults at risk for certain diseases or specific declines might enable them to take steps to influence later outcomes.

Workshop participants discussed revolutions in psychology and economics, in neuroeconomics, and in genetics and economics. Some pointed out that because these revolutions are occurring in parallel, understanding of how the brain directs economic behaviors is incomplete, and defining and refining economic phenotypes will be difficult. In addition, the field of genetics is constantly changing as more investigators further fine-tune how genes are defined and discover the effects of copy number and epigenetics on who we are. That being said, multidisciplinary teams of psychologists, neuroscientists, and economists should take advantage of existing technology and computing power and move forward with studies and consistently refine and adapt their phenotypes rather than wait for the revolutions to "lock in." Creativity, combined with available methods and technologies, should enable a multipronged approach that works both top down and bottom up.

Discussion throughout the workshop also considered the value of laboratory versus field experiments. The distance between these worlds is steadily decreasing, and investigators are expressing more and more interest in integrating them. The NIA is interested in encouraging these types of interactions. Although a formal RFA or PA will take some time to develop, investigators interested in understanding individual differences in economic behaviors are encouraged to discuss their ideas with NIA program staff.

Suggested Next Steps

The following were suggested as next steps and, in some cases, ways that the NIA can help.

- **A collaborative and empirical project building on diverse economic phenotypes to create a highly ordered structure explaining individual differences.** Such a project would combine personality variables with economic phenotypes of interest. Economists should offer subscales for psychologists and neuroscientists to use and incorporate subscales from these disciplines into their own studies. Workshop participants and others could participate in a planning session for data collection and proposal writing, and the NIA can foster development of the field with a RFA and by assembling the appropriate review group to review applications. The NIA also can assist with choosing economic phenotypes on which to focus.

How to carry out such a large-scale study is not clear. One approach could use self-report questionnaires and genotyping for the entire study sample, with a subset of participants undergoing neuroimaging. However, such a study would be expensive. Capitalizing on existing longitudinal studies that offer a wealth of psychosocial and genetic data might be more efficient. Leaders of large studies such as the HRS and Framingham Heart Study have expressed an interest in measures of economic behavior and personality characteristics.

- **Development of better measures, models, and standard language.** Psychological measurements have seen few advances over the course of a long period of time. Studies still rely on self-report questionnaires, which have several limitations, including what Duckworth described as “fakeability.” In addition, respondents tend to norm for their or their children’s age group when answering questionnaires. The fact that the majority of psychological research, about 98 percent, is still based on self-report questionnaires should change. New measures respecting domain and context specificity are needed.

Several participants noted that different investigators use the same word to describe different things. The same is true for tasks. Portfolios or tasks that measure the same characteristic should be constructed, and models should be developed to better measure and evaluate individual differences. Participants also noted that this workshop gave them a set of terms to use as they communicate with various groups.

The NIA can identify grant mechanisms to support large collaborations and the development of new measures. The Institute also can work with professional societies to support these types of initiatives. Workshop participants were encouraged to contact BSR with ideas.

- **Workshops to cross-train economists, neuroscientists, and psychologists.** Several participants discussed the need for workshops to familiarize investigators with the tools and language used by relevant disciplines. For example, economists could learn about statistical tools psychologists use, psychologists could learn more about economics tools for managing and interpreting real-world data, and neuroscientists could determine how to map onto existing models. The NIA could sponsor workshops to aid in this learning, and interested investigators could take advantage of existing workshops, such as those held by the Society for Neuroeconomics, that include cross-training sessions.
- **Incorporation of cognitive psychology in future studies.** Several workshop presentations emphasized the importance of mental representation and how knowledge is structured. Economic measures focus on steady-state behavior, but often individuals use the same information in different ways depending on how they learned it. Future work should recognize that behaviors are often adapted to changing environments.
- **Studies of the effects of aging on economic phenotypes.** Personality factors, age-related diseases, and caregiver issues should be explored in the context of economic decisionmaking. Studies assessing the types of decisions that are necessary, the neurological systems employed in these decisions, and the effects of age on those systems can provide a good view of the extent to which an aged person might be unable to make certain decisions. Shorter tasks can be used to further define where older persons are at risk and the types of advice they might need. Suzman encouraged the submission of applications for integrated projects and basic research relevant to aging.
- **A journal article to discuss issues in the field of economic phenotypes and genetics and to signal the NIA’s interest in them.** Some participants noted that this might be premature, but others contended that writing a position paper or journal article would help pioneers in this emerging field to organize their thoughts and elicit responses from others. Such a paper

should be published in a general interest journal, or it should be published in journals that will reach economists, psychologists, and neuroscientists.

APPENDIX 1: PARTICIPANT ROSTER

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APPENDIX 2: WORKSHOP AGENDA

Monday, September 10

8:30 am Continental Breakfast

9:00 am Introductions
Erica Spotts
Richard Suzman
David Reiss & David Laibson

9:30 am Overview

How the study of individual differences in economic behavior fits within the broader context of economic theory

David Laibson (20 min + 10 min discussion)

- Description of how traditional economic theory is being shaped and challenged by findings from neurobiology.
- General overview of the research being done using genetics & economic behavior, including updates on current projects from the Laibson lab.
- Information on new research in the areas of genetics and economic behavior.

10:00 am David Weir (20 min + 10 min discussion)

- Overview of current or future research from the HRS integrating genetics, economic behaviors & biomarkers, highlighting the unique opportunities presented by the HRS data for the study of individual differences in economic behaviors.
- Examples of the measurement of economic behaviors related to risk taking and intertemporal choice in the HRS data.

10:30 am Commentary Regarding Strategies and Methods

This commentary should be more broadly focused on how methods and strategies can be used to understand economic behaviors. Issues related to measurement of phenotypes should be addressed. Specific needs of population-based studies, or focus on experimental studies, also might be addressed.

Robert Krueger (20 min + 10 min discussion)

- Brief discussion of genetic methods and strategies that can be applied to the study of economic behaviors, both quantitative and molecular, if possible.
- General comments regarding the phenotypes being used (e.g., measurement issues, reliability).
- Are there any emerging approaches that could be applied?

- 11:00 am **Turhan Canli (20 min + 10 min discussion)**
- Focus on methods used to integrate genetics, phenotypes and neural pathways, addressing various imaging techniques such as fMRI, imaging genetics, etc.
 - What are the benefits of using these methods to better understand the phenotypes in question?
- 11:30 pm **Burt Singer (20 min + 10 min discussion)**
- Comments on issues related to using large-scale studies as a resource, specifically regarding strategies and challenges of integrating laboratory, survey, genetic and neuroimaging work.
- General Discussion**
- 12:30 pm **Lunch**
- 1:30 pm **Intertemporal Choice**
- Current State of Individual Differences Research in this Area*
- This section addresses how economists and psychologists might approach intertemporal choice/delay of gratification differently, including measurement and power issues, the role of this domain in aging, how early childhood development informs adult behavior and what we know in terms of genetic effects on intertemporal choice.
- Walter Mischel (20 min + 10 min discussion)**
- Discuss longitudinal research on intertemporal choice/delay of gratification, including how measurement changes over time, and describe what is currently known about early life indicators of later life economic behaviors.
 - Describe plans for integration with genes and biomarkers.
- 2:00 pm **David Laibson & Daniel Benjamin (20 min + 10 min discussion)**
- Discuss economic models of intertemporal choice, how these are tested using experimental manipulations and behavioral and neuroimaging methods, how the integration with genetics can advance our understanding of individual differences in this domain, including a discussion of measurement and power issues.
- 2:30 pm **Trey Hedden (20 min + 10 min discussion)**
- Describe ongoing research in neuroeconomics of aging, with a specific focus on methods for studying individual differences in intertemporal choice combining neuroimaging and behavioral methods.
- 3:00 pm **Commentary**
- Commentary should focus more specifically on intertemporal choice and any issues specific to this domain.

Angela Lee Duckworth (10 min)

- Describe how the concept of self-discipline relates to this behavioral domain. Are there different measurement issues? Is there a slightly different conceptualization?

Robert Krueger (10 min)

- Comments could include ways to add genetic data to phenotypic studies, what genes might be involved in these behaviors, the best strategies to consider (quantitative, molecular).
- Are there issues from personality research that are relevant here?

Turhan Canli (10min)

- Focusing specifically on intertemporal choice, comment on proposed and alternative strategies from a neuroscience perspective, and what additional data or infrastructure might be needed to add neuroscience (e.g., fMRI, imaging genetics).
- How are the strategies that were mentioned in the morning session relevant here?

General Discussion

5:00 pm

Adjourn

7:00 pm

Dinner at Rock Creek Restaurant

4917 Elm Street, Bethesda, Maryland (301-907-7625)

Tuesday, September 11

8:00 am

Continental Breakfast

8:30 am

Risk and Loss Aversion

Current State of Individual Differences Research in this Area

Elke Weber (20 min + 10 min discussion)

- Describe behavioral economic and psychological measurement of risk attitudes, risk perception, loss aversion and related constructs, including current methods for the study of individual differences in these domains, and current knowledge of the predictive power of these individual difference measures.
- Discuss relevance to aging and opportunities for integration with neuroimaging and genetics, where appropriate.

9:00 am

James Blair (20 min + 10 min discussion)

- Describe biological approaches to risk taking and impulsivity and how special populations can offer insights into these behavioral domains.
- Provide an overview of methods and strategies, findings, how these methods can help delineate the genotype-phenotype link.

9:30 am	<p>Commentary</p> <p>Robert Krueger (10 min)</p> <ul style="list-style-type: none"> • Comments could include ways to add genetic data to phenotypic studies of risk and loss-related behaviors, what genes might be involved, what are the best strategies to consider (quantitative, molecular). • Is personality research on impulsivity relevant here? <p>Turhan Canli (10 min)</p> <ul style="list-style-type: none"> • Focusing specifically on risk and loss behaviors, comment on proposed and alternative strategies from a neuroscience perspective. What additional data or infrastructure might be needed to add neuroscience (e.g., fMRI, imaging genetics). • How are strategies discussed yesterday relevant here?
10:00 am	General Discussion
12:00 pm	Lunch
1:00 pm	<p>Discussion and Wrap Up</p> <ul style="list-style-type: none"> • Future directions: measurement and data needs, research gaps and emerging opportunities in the study of economic phenotypes of relevance to aging.
2:30 pm	Adjourn